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PRELIMINARY MANUSCRIPT FOR PROPOSED ORDNANCE PAMPHLET

"AIRCRAFT CHEMICAL SMOKE AND VESICANT

SPRAY, dated 1 JULY 1943 "

W.H.P. Blandy

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15 September 1943

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NAVY DEPARTMENT  
BUREAU OF ORDNANCE  
Washington, D.C.

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15 September 1943

ALIO-3  
(Be5f)

From:  
To:

The Chief of the Bureau of Ordnance  
The Commander Air Force, Pacific  
The Commander Air Force, Atlantic  
The Commander Aircraft, South Pacific Force  
The Commander Aircraft, Southwest Pacific Force  
The Commander Fleet Air, South Pacific  
The Commander Fleet Air, West Coast  
The Commander Fleet Air, Alameda  
The Commander Fleet Air, Houston  
The Commander Fleet Air, Quonset Point  
The Commander Fleet Air, Seattle  
The Commander Fleet Air Wing FIFTEEN  
The Commanding General, Marine Aircraft Wings, Pacific  
The Commanding General, Marine Fleet Air, West Coast

Subject: Preliminary Manuscript for Proposed Ordnance Pamphlet  
"Aircraft Chemical Smoke and Vesicant Spray", dated  
1 July 1943

Enclosure:  
(Herewith)

(A) One copy of subject manuscript

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1. Enclosure (A) is hereby forwarded to the above addressees for information and reference purposes in case of emergency. It is pointed out that the formulas given in Chapter 3, paragraph 5(a), "Technique of Vesicant Spraying," were developed academically and have not been checked by spray tests. It is believed that the technique given is sound in principle. Any additional information obtained concerning the technique of spraying will be disseminated as it becomes available.

2. It is not desirable to publish the subject manuscript as an Ordnance Pamphlet until a description of a new pressure type spray tank, now under development, can be included and until the formulae mentioned above have been substantiated by extensive spray tests. It is anticipated that Ordnance Pamphlet No. 723, "Aircraft Smoke Screen Equipment," will be replaced by a new Ordnance Pamphlet based on the subject manuscript.

HEM/ama

W. H. P. BLANDY

Copy to:

Index (w/ Encl. (A))  
BuShips  
FCMO  
BuPers  
AAF (Chem. Office)  
U.S. Tech. Div.

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Signed by  
G. F. Hussey, Jr.  
Acting

CANCELLED



IN REPLY ADDRESS  
BUREAU OF ORDNANCE, NAVY DEPARTMENT  
AND REFER TO NO.

NAVY DEPARTMENT  
BUREAU OF ORDNANCE

WASHINGTON, D. C.

29 OCT 1943

(Re 5f)

710-3

From: The Chief of the Bureau of Ordnance.  
To: Chemical Warfare Service,  
Technical Division,  
Edgewood Arsenal,  
Edgewood, Maryland.  
(Attn. Capt van de Erva)

Subject: Forwarding of Preliminary Manuscript  
on Aircraft Spray.

Reference: (a) Telephone conversation between  
Capt. van de Erva, C.W.S., and a  
representative of BuOrd held 28 Oct.  
1943.

Enclosure: BuOrd (Re 5f) conf. ltr. A10-3 (with encl.)  
(H.W.) dated 15 Sept. 1943.

1. As requested by reference (a), enclosure (A)  
is forwarded herewith for information and retention.

W. H. P. BLANDY

HBL/os

*E. A. Jungmann*

E. A. JUNGMAN  
By direction

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1 July 1943

Aircraft Chemical Smoke and Vesicant Spray

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1. Scope. This pamphlet contains a description of the technique for the employment of a chemical smoke and spray by aircraft, a description of the various pieces of equipment and materials used in chemical smoking and spraying, and instructions and precautions that should be observed when using the chemical smoking and spraying equipment or handling one of the chemical agents.

2. Definition. Aircraft chemical spraying is defined as the spraying or dispersing of liquid chemical agents in droplets or an atomized form from tanks carried on an airplane. Thus "spraying" includes "smoking".

3. Use of Aircraft Chemical Spray. Aircraft chemical spray may be used for:

- (a) Producing casualties (war gases)
- (b) Harassing the enemy (war gases)
- (c) Denying areas to the enemy (persistent vesicant spray)
- (d) Reducing visibility (smoke screens)

A thorough understanding of the various uses and limitations of aircraft chemical spray and the equipment is essential.

4. Materials Used for Aircraft Chemical Spray. Aircraft chemical spray can be divided into two main types according to the chemical agents used, smoke and vesicant spray.

(A) FS smoke mixture is the chemical agent commonly used for reducing visibility by producing a smoke or fog. FS is a sulphur trioxide-chlorosulfonic acid mixture which weighs approximately 15.8 pounds per gallon. FM smoke mixture (titanium tetrachloride) may also be used; its weight is approximately 14.5 pounds per gallon.

(B) A persistent vesicant, usually mustard (H) or Lewisite (L), or a mixture of these vesicants, is the principle type of chemical agent used for denying areas to the enemy, harassing the enemy, or producing casualties. Chemical freezing deterrents and stabilizers are sometimes mixed with H. Thickening agents are generally used in all vesicants for high altitude spraying. Many newly developed

war gases and also many old ones such as ethyldichlorarsine (ED), chloracetophenone solution (CNS), etc., may be sprayed from aircraft for producing casualties or for harassing purposes. Another chloracetophenone solution (CNB), the common riot-dispersing tear gas, is primarily used in training of air corps units in the technique of offensive use of chemicals and for the training of ground troops in the performance of their duties during and after such attacks. Molasses residuum solution (MR), a harmless, dark brown liquid that is easily discernible on almost any surface, is used extensively for simulating mustard gas in testing new spray tank installations for possible contamination of the airplane, and to determine the characteristics, concentrations, etc., of the spray patterns. MR (3 parts water and 1 part molasses residuum by volume) is valuable in training pilots to hit a target with spray since a record (dark brown spots) is left on the area sprayed.

##### 5. Equipment Used for Aircraft Chemical Spraying.

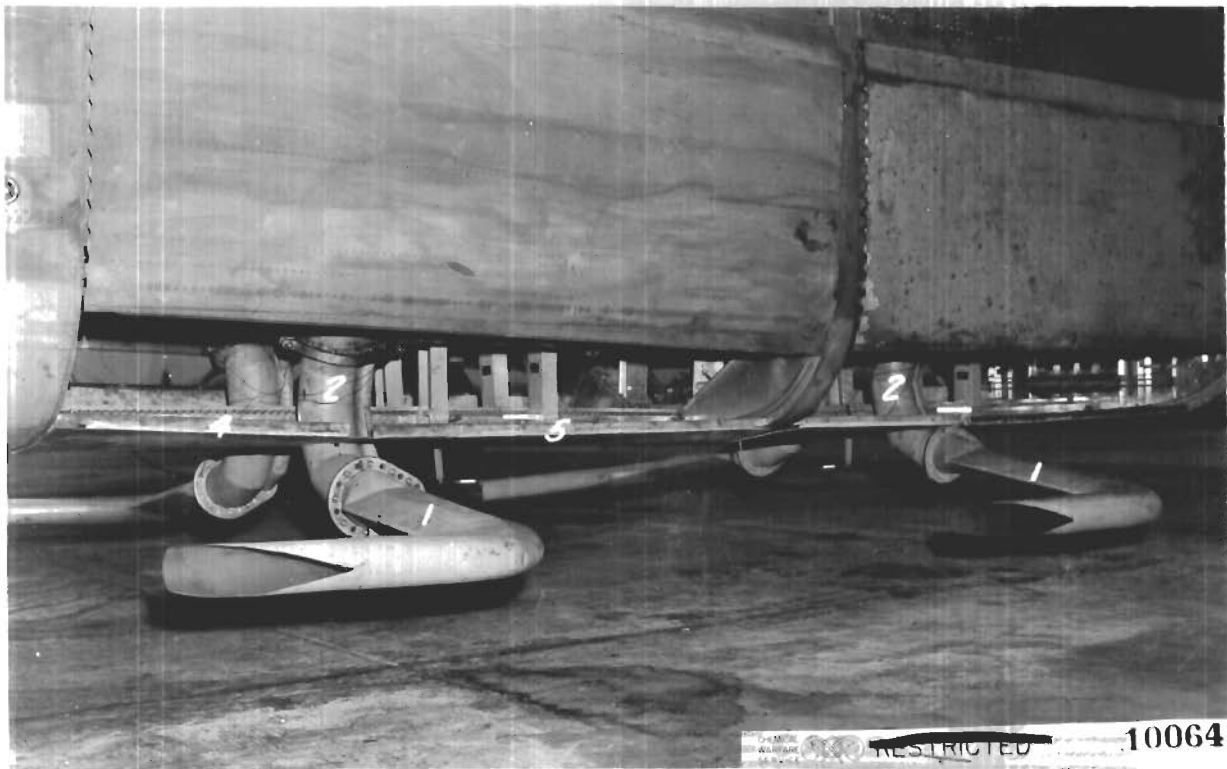
(A) Smoke screen tanks can be used for spraying liquid chemical agents. The Navy Mark 5 type tank is available for general use although it was designed principally for laying smoke screens. Both the Mark 5 and Mark 6 type smoke screen tanks require carbon dioxide equipment for discharging the liquid chemical agent. The Mark 6 type tank is obsolescent, being replaced by the larger capacity Mark 5 type tank. When either of these tanks are carried in a bomb bay, the straight exhaust tube, which is used for wing installations, must be replaced by an auxiliary hinged exhaust tube. The Navy Mark 7 type tank is a wing tank that uses the gravity flow principle. This tank is even smaller than the Mark 6 type tank, and is considered obsolete for this reason and also because FS smoke mixture cannot be stored in it for more than several days. The Mark 7 type tank, however, is covered in this pamphlet because in an emergency it can be obtained and made satisfactory for storing vesicants, but not smoke mixtures. In order to transfer the liquid chemical agent from a shipping drum (55 gallon capacity) to the smoke screen tank, the Navy provides the Mark 1 (for Mark 5 and 6 type tanks) and the Mark 1 Mod 1 (for Mark 7 type tanks) chemical filling equipment. Since the only essential difference between the Mark 5 and Mark 6 type tanks is their size, the chapter on the Mark 5 type tank is applicable in general to the obsolescent Mark 6 type tank.

(B) To familiarize the Service with the Army spray tanks, which are being mocked-up on Naval aircraft, the following brief information is given. Information concerning the adaptibility of these tanks to Naval aircraft will be disseminated as soon as practicable. The Chemical Warfare Service of the Army has developed several sizes of gravity flow spray tanks, all of which employ frangible closure discs (glass) in the air inlet and discharge lines instead of quick-opening valves. The air inlet and discharge lines are opened by blowing out the glass dams (discs) with No. 4 electric blasting caps (detonators). These tanks are constructed of light gage mild or copper-bearing steel; this fact combined with the use of the frangible closure discs instead of heavy valves



M10 SPRAY TANK MOUNTED ON WING OF A36

FIGURE 1



M33 SPRAY TANK DISCHARGE LINES FROM THE B24 (PB4Y)

FIGURE 2



133 SPRAY TANKS MOUNTED IN BOMB BAY OF B24. (PB4Y)

FIGURE 3



reduces the weight considerably. It may not be feasible to store the very corrosive FS smoke mixture in these light tanks for long periods, but if the air inlet shipping plate or plug and the discharge shipping plate are installed, vesicant war gases may be stored in them for at least six (6) months. Before use the shipping plug and plate must be removed and, if not already in place, the glass discs must be installed. This job should be done only by experienced personnel provided with complete protective equipment. The detonators should never be installed until just before the tanks are to be mounted on the airplane for use. The M-10 spray tank weighs about 68 pounds empty (wing tank only), has a flow rate of approximately 5 gallons per second, and a capacity of 30 gallons of chemical agent. The M-33 spray tank weighs about 175 pounds empty (wing or bomb bay tank), has a flow rate of approximately 10 gallons per second, and a capacity of 70 gallons of chemical agent. The M-10 spray tank may be suspended from any double hook (14" spacing), wing, bomb rack (see Figure 1), while the M-33 spray tank has carrier lugs spaced 30" apart and requires a special exhaust tube for particular installations (see Figures 2 and 3). At present the M-33 tanks can be installed on certain Navy airplanes common to both the Army and Navy.

(1) The Army M-20 and M-21 smoke tanks are identical to the Navy Mark 5 and Mark 6 types, respectively, except that the Army tanks are constructed of mild or copper-bearing steel instead of monel.

Chapter 2  
Chemical Agents

1 July 1943

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1. Vesicants - A persistent vesicant is used for aircraft chemical spraying. The vesicant used may be one of several chemical agents or a mixture of these agents; however, the vesicants likely to be employed will, in general, be mustard or lewisite, or chemical agents similar to these war gases. The choice of the agent or mixture of agents used will depend upon the season of the year, the location of the theatre of operation in which the agent is to be used, the general strategic objective of the campaign, and the material available at the time. In general, persistent vesicants are referred to as gases although they are actually oily liquids which have a high boiling point. The physical properties of a mixture generally are similar to the physical properties of its components, making due allowance for the proportion of each component.

2. Mustard Gas (H) - Mustard is a compound of carbon, hydrogen, sulphur, and chlorine, having the formula  $(Cl C_2 H_4)_2S$ . It resembles a light lubricating oil in its physical properties, the commercial product being brownish black in color. Mustard is not only a highly vesicant material but also a powerful lung irritant. It attacks all unprotected parts of the body, producing severe burns and blisters; it also attacks the whole respiratory system producing inflammation of the trachea and bronchi with necrosis (gangrene) of the mucous membrane. Pure mustard is colorless and nearly odorless. The plant product in low concentrations has the odor of garlic or onions. In higher concentrations, it comes decidedly pungent and irritating. Pure mustard, on cooling, forms a white, crystalline solid which melts at  $58^{\circ} F$ . The melting or freezing point of the impure

plant product is lower than that of the pure substance being 46° to 50° F. A fairly definite relationship has been found to exist between the melting point and the purity of the material, and this has been used to determine the "purity" of the manufactured product. The pure liquid boils at approximately 443° F; however, at this temperature some decomposition takes place.

(A) The density of liquid plant mustard and the corresponding specific volume for different temperatures are:

<u>Temperature</u>		<u>Density</u>	<u>Specific Volume</u>
<u>°F</u>	<u>°C</u>	<u>lb/gallon</u>	<u>gallon/lb.</u>
32 <sup>1</sup>	0	11.46	0.0873
50	10	11.37	0.0880
59	15	11.33	0.0882
68	20	11.29	0.0886
77	25	11.24	0.0889
86	30	11.20	0.0893
95	35	11.16	0.0896
149	65	10.90	0.0917

#### 1 Solid

It will be seen that if a quantity of the liquid at 50° F. is heated to 149° F. it will increase in volume by an amount which is:

$$\frac{0.0917 - 0.0880}{0.0880} \times 100 = 4.2 \text{ per cent}$$

While it is probable that extreme temperature changes were chosen for the above example, it is evident that a void must be left when filling any container with mustard in order to allow for this volume change. Mustard, both in the liquid and solid state, vaporizes with the resulting vapors tending to seek the low areas as the mustard vapors are heavier than air.

(B) The volatility of mustard gas at 104° F. is 3.59 milligrams per liter (or ounces per thousand cubic feet). The maximum concentration obtainable at this temperature, by evaporation of the liquid is 50 times the lethal concentration for a 30 minute exposure. However, this maximum concentration can be maintained by evaporation only if the air remains in contact with the liquid for some time. This is impossible in the field where the air is practically always in motion. However, if only a light wind is blowing and this has to pass over a considerable area drenched with mustard, the concentration of the vapor in

the air will accumulate and more nearly approach the saturation point for the existing temperature. As the temperature decreases, the volatility of the liquid mustard will likewise decrease, thereby decreasing its effect by decreasing the amount of vapor which can be kept present in the air. No accurate vapor pressure data for solid mustard are available. After a substance has become a solid the decrease in vapor pressure with a drop in temperature takes place faster than while the substance is in the liquid state. It is for these reasons that a substance like mustard, where temperature and wind conditions affect the results considerably, can be used to advantage only when the particular conditions under which they are to be used are favorable.

(C) Because of its low vapor pressure, mustard vaporizes very slowly giving it a high degree of persistency. Also, because of this property, a high concentration of mustard vapor cannot ordinarily be obtained by the vaporization of the liquid. When dispersed in spray form as from an aircraft smoke screen tank (see Figure 4) the vaporization of the liquid will be greatly hastened because there is a much greater surface of the liquid exposed to the air which greatly facilitates the vaporization of the liquid. Hence, by spraying, higher concentrations of the vapor can be obtained that would normally be obtained by a quantity of liquid evaporating into the atmosphere. In fact, if the liquid is sufficiently atomized it may remain floating in the air as a fog consisting of minute droplets of liquid, thereby yielding a concentration above that attained in a saturated vapor at ordinary temperatures. Such accelerated vaporization decreases the persistency of mustard. Also, because in normal conditions, the wind is constantly moving, the vapors are rapidly dispersed over a large area which immediately tends to nullify any gain that may have been obtained by getting rapid vaporization, since the concentration over a given area may not be retained long enough to produce casualties. The rapid breaking up of the spray into small droplets also decreases the chances of hitting personnel with a quantity of liquid drops sufficiently large to penetrate the clothing and cause burns.

(D) Mustard is practically insoluble in water but is readily soluble in various hydrocarbons and other organic solvents, such as gasoline, kerosene, carbon tetrachloride, monochlorobenzene, and carbon disulfide. For this reason any of these solvents can be used to wash off mustard; however, these solvents do not destroy it.

(E) Mustard and lewisite are readily absorbed by rubber, leather and wood, or other porous articles, and in a short time penetrates rubber boots, gloves, or other articles of clothing



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MLO SPRAY TANK  
MOUNTED ON A20 (BD)  
SPRAYING MUSTARD (H)

FIGURE

if these are brought into direct contact with the liquid. Therefore, most articles of clothing unless they have been treated (impregnated), will not protect against liquid mustard or lewisite. The same can be said about mustard and lewisite vapors; they will penetrate most untreated clothing.

(F) At ordinary temperatures, mustard is a rather stable compound. Although it is not soluble in water, it undergoes very slow hydrolysis on contact with water with the formation of hydrochloric acid and other harmless compounds. Mustard which has been scattered on the ground becomes hydrolyzed by the water present in 2 days to 2 weeks depending on the concentration of mustard present, the amount of water, and the temperature. The greater the amount of water and the higher the temperature, the more rapid the hydrolysis. Since the products of the hydrolysis are non-toxic, water will destroy mustard in time. However materials such as bleaching powder (chloride of lime) or other substances which liberate free chlorine will neutralize mustard much more rapidly and can be used for decontaminating agents.

(G) Mustard has no appreciable action on monel, iron, steel, lead, brass, copper, bronze, aluminum, zinc, or tin at ordinary temperatures. It may be stored in monel or steel containers for at least six months. Longer periods may be inadvisable because of the tendency of the impure agent to decompose and form a sludge and gas.

3. Lewisite (L) -Lewisite is a compound of carbon, hydrogen, chlorine, and arsenic. Its physical properties are much like mustard being a heavy oily liquid, dark brown in color (commercial product), and has a high boiling point. Both the boiling and the melting or freezing point are lower than that of mustard as it boils at approximately 350°F. as compared to 450°F. for mustard, and melts or freezes at a temperature of approximately 0°F. rather than at 46-50° F. Lewisite has strong vesicant properties and is also a powerful respiratory irritant and systemic poison.

(A) The density of commercial liquid lewisite and the corresponding specific volume for different temperatures are:

Temperature		Density	Specific Volume
°F	°C	lb/gal.	gal./lb.
32	0	15.97	0.0626
50	10	15.85	0.0631
59	15	15.77	0.0634
68	20	15.71	0.0636
77	25	15.64	0.0639
86	30	15.57	0.0642
95	35	15.51	0.0645
149	65	15.11	0.0666

It will be seen that if a quantity of the liquid at 50°F. is heated to 149° F. it will increase in volume by an amount which is:

$$\frac{0.0666 - 0.0631}{0.0631} \times 100 = 5.55 \text{ per cent}$$

Thus, any container which is filled with lewisite must have a sufficient space after filling to allow the liquid to expand should the temperature increase.

(B) Lewisite, as does mustard, will vaporize from both the liquid and the solid state, and its vapors being considerably heavier than air will tend to seek low areas. Although the vapor pressure for lewisite is quite low for all ordinary temperatures, its vapor pressure is higher than that of mustard. Therefore, its persistency under the same conditions is less than that of mustard.

(C) Lewisite has a faint but unpleasant odor which resembles that of geraniums. Even in a low concentration, lewisite vapors produce a disagreeable burning sensation of the nose and throat and sometimes violent sneezing which afterwards may be accompanied by a state of nervous depression.

(D) Benzine, gasoline, kerosene, alcohol, and a number of other solvents dissolve lewisite and can be used to remove it from a given surface; however, these solvents do not destroy it.

(E) Lewisite is practically insoluble in water, but it hydrolyzes readily with the formation of hydrochloric acid and L oxide (a solid) which in contact with the body is a very toxic and poisonous chemical agent. Water therefore, cannot be used to render lewisite non-toxic as eventually it does mustard, though it can be used very effectively to hydrolyze lewisite and wash away the solid L oxide. Since the vaporization of L oxide is negligible and the fact that poisonous arsenic compounds always occur with lewisite (regardless of the decontaminating agent), liberal amounts of water (fresh or saline) should always be used to wash away this highly insoluble, poisonous residue.

(F) Lewisite is a stable chemical agent and may be stored for long periods of time without any appreciable change in composition. It has no action on monel, iron, steel, brass, copper, bronze, aluminum, zinc, or tin at ordinary temperatures, but it does attack lead slightly, and it may be stored in steel

containers for a year or more.

(G) Protection against lewisite liquid or vapor form is the same as that for mustard, though lewisite is best removed from surfaces by an alcohol solution of sodium hydroxide; a slurry of chloride of lime (bleach or calcium hypochlorite) may be used to destroy it in the field since lewisite hydrolyzes readily.

#### 4. Nitrogen Mustards

(A) Up to the present time the presence of war gases in dangerous concentrations could be detected by their characteristic odors. Now, however, very potent chemical agents have been developed which have very little odor, which resembles fish or soap, even in high concentrations. It can readily be seen then that extra precautions must be taken in order to detect these agents, especially when they are present in effective concentrations and in combination with the customary odors of battle. The term "nitrogen mustards" might be used to include a few of these practically odorless agents. HN-2 and HN-3 are examples. Most of these nitrogen mustards are fairly readily hydrolyzed by water, but the products of hydrolysis are toxic.

(1) HN-2 is a liquid at ordinary temperatures with a very low freezing point. It will therefore remain as a liquid in all climates excepting only the extreme cold of the Arctic. At elevated temperatures it is not particularly stable so it might not be effective in hot climates. At ordinary temperatures it is three or four times as volatile as ordinary mustard so would be less persistent. The liquid is a vesicant in contact with the skin. It is not as vesicant as mustard but the blisters may not develop for about 24 hours. The vapor of HN-2 which, because of its volatility may be in high concentration has a marked effect on the eyes causing blindness.

(2) HN-3 is a solid at ordinary temperatures. It is stable but not very volatile. This solid is a vesicant also.

(B) The nitrogen mustards act as vesicants or irritants to all exposed tissues, including the eyes, skin, respiratory tract and stomach. Systemically these agents damage the blood-forming organs and certain areas of the central nervous system. They destroy the white blood cells. Mild exposures, however, will probably not cause noticeable systemic symptoms. The greatest danger from this gas lies in the fact that eyes and lungs may be damaged before the presence of gas is suspected, if reliance is placed on smell alone.



(C) The best skin decontamination for nitrogen mustard is soap and water. Clothing can be decontaminated by aeration and/or washing by the standard laundry method. The protective ointments are also effective. For decontamination of materiel and ground the standard methods of bleach, boiling water, or swabbing with gasoline are effective. Protection against the nitrogen mustards is the same as that for other vesicants.

#### 5. Freezing Deterrents for Mustard Gas

(A) Several solvents such as monochlorobenzene, ethylene dichloride, dichloro ethyl ether, carbon disulphide, acetone, carbon tetrachloride, etc, may be mixed with H to increase stability in storage and to lower the freezing point; however, the addition of a non-toxic solvent may seriously lower the toxicity if employed in large proportions. The vesicant action of liquid H is not reduced as much as the effective vapor concentrations by the addition of a non-toxic diluent. The reasons for this presumably being that only the very small amount of H (very thin layer) actually in contact with the skin contributes to the vesicant action, while the absolute H vapor concentration is not only decreased in direct proportion to the amount of diluent present, but also the more volatile solvent vaporizes separately and more readily, producing a cooling effect which tends to delay the vaporization of H until the solvent has vaporized. (The vesicant action of diluted H should be kept in mind when using a solvent to remove H from the skin. A very careful technique must be followed. The solvent should not be allowed to run from the contaminated to the unaffected skin as it will carry the vesicant and extend the damage.) The percentage composition by weight of the solvent in H, the percentage decrease in effective vapor concentration, and the decrease in degrees Fahrenheit of the freezing point are numerically equal for practical purposes. For example, 10% solvent by weight in H decreases the vapor (H) concentration 10% and lowers the freezing point 10° F. A mixture of H and a solvent remains a slush at temperatures below the freezing point of the mixture thereby furnishing a convenient safety factor.

(B) The ideal freezing deterrent for H appears to be HN-2, the nitrogen mustard with a very low freezing point. HN-2 is not as vesicant as mustard, but it is three or four times as volatile; hence, a mixture of H and HN-2 in almost any desired proportions may provide an excellent low temperature

vesicant that can be stored for long periods.

(C) The use of L (lewisite) to lower the freezing point of H (mustard) has the advantage of also being toxic, but the mixture is not suitable for storage. The mixture consists of equal quantities of H and L by weight or volume, the latter being preferred because of its slightly better storage characteristics and lower freezing point of minus 20°F. as compared to 0°F. for the former mixture. From present indications, mixtures of H and L appear particularly undesirable for use from the viewpoint of storage, that is, the mixture is much more corrosive than either of its constituents, and decomposition, the generation of gas pressure, and gum-formation take place no matter what the nature of the container. For this reason mixtures of H and L should not be stowed for longer periods than two weeks at any temperature unless required by military necessity, in which case, its use is not feasible after one month in view of the decomposition which destroys the vesicant action of the mixture. During this decomposition gums are formed which would restrict flow out of the tank. This undesirable reaction accelerates as the temperature is raised, being very rapid at temperatures considerably above 110° F.

#### Densities of Mustard-Lewisite Mixtures

<u>Temperature</u>		<u>HL*</u>	<u>HL**</u>
<u>°F</u>	<u>°C</u>	<u>lb./gal.</u>	<u>lb./gal.</u>
32	0	13.42	13.39
50	10	13.31	13.28
59	15	13.26	13.22
68	20	13.20	13.16
77	25	14.14	13.10
86	30	13.09	13.04
95	35	13.04	12.99
149	65	12.71	12.64

\*HL of 50/50 mixture by weight of H and L (0°F. freezing point)

\*\*HL of 50/50 mixture by volume of H and L (-20°F. freezing point)

6. Thickening Agents - A thickening agent is desirable for other than low altitude spraying of vesicants to increase the drop size of the spray which increases the rate of fall, thereby making higher altitude spraying more accurate and feasible in actual practice. Within limits the thickeners are useful for obtaining an optimum drop size for penetrating clothing and producing casualties. The study of thickened vesicants is not complete, so until definite data concerning stability is available, such mixtures should not be relied upon for long term storage.

7. Screening Smokes - A smoke is a cloud of minute particles of solids, liquids, or both which are suspended in a gaseous medium, usually air. In a broad sense this also includes fogs which are clouds of minute droplets of water suspended in the air. These particles may vary in size from those that are large enough to be seen by the unaided eye to those which approach the size of a single molecule.

(A) Smoke particles have an irregular, jerky, aimless movement which is due to the collisions of the various particles of the smoke mixture with each other and with the molecules of the air. By virtue of this movement, the smoke particles gradually diffuse and spread. The larger particles of smoke mixtures naturally diffuse more slowly than the smaller ones, not only because of the greater resistance of the medium in which they are suspended but also because of the lower velocity of the larger particles. However, the general circulation of the atmosphere (winds and convectional currents) is a far more important factor in the dispersion of smokes than is diffusion; in fact, in comparison with wind and convectional currents, diffusion is negligible.

(B) Due to various causes, smoke particles have a tendency to increase in size. One of these is the cohesion or coalescence of the particles as they are brought in contact with each other. This effect is negligible in the case of dry solid particles, but with liquid droplets or the particle of a solid upon which some water has condensed, this tendency of the particle to grow in size becomes more pronounced. Another cause of the growth of smoke particles is their absorption of water from the air. This is especially true of water-absorbing substances such as sulphur trioxide. As a result of this increase in size, the average rate of settling of the smoke particles also increases.

(C) A screening smoke attains its object not so much by the actual obstruction of the light rays (except in very dense



SMOKE SCREEN

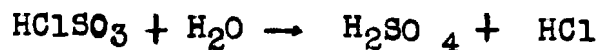
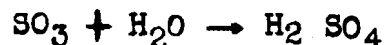
FIGURE 5

smokes) as by scattering the light rays due to the reflection and refraction by the many smoke particles. The number of particles, rather than the size of the particles determines the efficiency of a smoke to screen an object. Consequently it is desirable to have a smoke material divided as finely as possible down to a certain minimum size of particles, not only because in this form the material will remain suspended longer but also because a given quantity of smoke material will yield a larger number of particles and hence will be more efficient. A screening smoke may be used in sufficient density to entirely destroy visibility or in less quantity to create a haze which only lowers visibility. It is not the total amount of light prevented from passing through the smoke screen that is important, but it is the percentage of rays which are diffused, refracted, or reflected by the smoke. For this reason a white smoke is a more effective screening agent than a black smoke which depends upon absorption and obstruction of the light rays for its screening. The total light coming through a black smoke is probably less than that coming through a white smoke, but the percentage of rays coming through a black smoke without being refracted or reflected is greater than that coming through a white smoke. This permits a greater visibility through a given quantity of black smoke than would be possible through the same quantity of white smoke. Also the blinding effect produced by direct reflection of light from the white smoke is lost in case of a black smoke.

(D) Liquids which react with the moisture in the air, such as FS (sulphur trioxide in chlorosulphonic acid) and FM (titanium tetrachloride) are used for laying smoke screens from aircraft. These materials at ordinary temperatures are liquids, and when sprayed from an airplane they hydrolyze when they come in contact with the moisture in the air. The minute particles formed by this hydrolysis diffuse the light rays tending to pass through them. Since these materials (FS and FM) depend to a large extent upon moisture in the air for their greatest effect, conditions in the air favorable for producing a good smoke screen with a minimum amount of liquid smoke material require a high moisture content. Thus, if the humidity of the air is low, there will be insufficient moisture present for complete hydrolysis, and more smoke material will be required to produce a good screen. Temperatures considerably below freezing ( $32^{\circ}\text{F}$ ) are not favorable for laying smoke screens with these chemicals as the absolute moisture content is low even though the relative humidity may be fairly high.

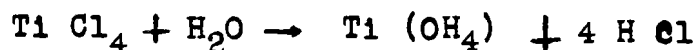
8. FS Smoke Mixture - FS smoke mixture is a solution of sulphur trioxide in chlorsulphonic acid; the solution consists of approximately 55 per cent sulphur trioxide and 45 per cent chlorsulphonic acid by weight. The purpose of the chlorsulphonic acid is to keep the sulphur trioxide in a liquid state at the lowest temperatures likely to be encountered. With the 55-45 mixture, the  $\text{SO}_3$  remains a liquid until temperatures below minus  $22^\circ \text{F}$ . are reached. Any appreciable increase in the  $\text{SO}_3$  content raises the freezing point to within the normal winter temperatures.

(A) While the chlorsulphonic acid ( $\text{HClSO}_3$ ) has fair smoke-producing qualities, the sulphur trioxide is the chief contributor. Both constituents depend upon hydrolysis to produce smoke. This reaction is as follows:



The sulphuric and hydrochloric acids thus formed continue to absorb moisture until an equilibrium condition is reached with the water vapor present. High humidity increases the effectiveness of the smoke produced. The smoke produced causes irritation of the skin and throat but is harmless since the concentration of acid in a smoke is very low. The liquid FS, which practically always has some water present, has very strong corrosive properties resembling a strong mineral acid. However it has a very slight reaction with monel as compared to other metals. It should be noted that water-free FS is relatively non-corrosive and is usually shipped satisfactorily in tightly-sealed steel containers.

9. FM Smoke Mixture - FM smoke mixture, or titanium tetrachloride, is a colorless liquid which hydrolyzes when it comes in contact with moisture as follows:



Titanium hydroxide is water-absorbing and thus the smoke soon becomes composed of combined solid and liquid particles. The hydrochloric acid, being hygroscopic, also helps to form the smoke. The smoke produced from FM is harmless and only slightly irritating. Moisture should not be allowed to come in contact with FM as traces of moisture cause the

formation of solid titanium hydroxide which tends to settle and might cause trouble on discharge. FM produces a good smoke with average humidity and is considered better than FS in cold weather, but the smoke tends to dissipate rather rapidly. With a higher humidity the smoke dissipates more slowly. FM is corrosive, but not nearly so much as FS smoke mixture.

Chapter 3

1 July 1943

Weather and Terrain Factors and the Technique of  
Aircraft Chemical Spray

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1. General

(A) Gas can penetrate into places which are well protected from gunfire. The targets are groups and areas rather than individuals; therefore, casualties may be expected in large numbers when they occur. Chemical agents produce results under field conditions which depend upon a number of factors that are frequently hard to estimate accurately. The persistency and the quantity of agent used, the area affected, the meteorological conditions, the protection available to troops, their gas discipline and physical condition are all important factors which must be considered. In general, the effect of a chemical agent is approximately proportional to the concentration and the time of exposure. Practically, however, any mathematical expression of this relationship is of limited application, due to the wide variation in conditions affecting the behavior of agents after release and to variable human resistance to these agents.

(B) Persistent vesicant spray is employed to produce casualties among personnel and animals and to contaminate special targets or areas occupied by the enemy, or to deny areas to the enemy. When the latter is the purpose, it may be necessary to repeat spray attacks daily, in view of the fact that the agent is only moderately persistent when sprayed because it is broken up into relatively small droplets which may evaporate away in 24 hours or less.

(C) In contrast to the first World War, because of the introduction of the airplane into chemical warfare, chemical warfare





CHEMICAL  
WARFARE  
SERVICE

10263

MIC SPRAY TANKS MOUNTED ON P38 SPRAYING MR

FIGURE 6



**M33 SPRAY TANK  
ON B-25 (NAVY PBJ)  
SPRAYING MOLASSES  
RESIDUUM (MR)**

**FIGURE 7**

operations may be employed almost anywhere, reserve and rear areas as well as in forward areas. Chemical warfare operations in rear areas may be especially effective at ports, airfields, rail centers, and along lines of communication. The most effective use of persistent agents in heavy concentrations will probably be to neutralize or force evacuation of areas. Spraying is not recommended for use against ships underway unless conditions are ideal, since moving ships, not surprised, may dodge the spray unless it is delivered from very low altitudes, and this type of spraying in face of antiaircraft fire would be too costly to justify the doubtful results to be obtained. In general spray missions should be accomplished at high speed, at low altitude, and under conditions of surprise. Night spraying is useful in obtaining surprise and the necessary protection from strong antiaircraft defenses.

(D) The determination of when and where to use persistent vesicant spray, and the application of the proper amount of the proper agent, constitute the tactics of spraying vesicants. This requires an understanding of the power and limitations of the agents and spray tanks available.

## 2. Weather and Terrain Effect on Vesicant Spray Droplets.

(A) High wind velocity and high temperature both increase the rate of evaporation of persistent agents and thereby decrease the period of effectiveness; however with persistent agents the liquid rather than the vapor is usually relied upon for physiological effect; therefore, the wind velocity and direction primarily effect the ability to hit the target, while a low temperature decreases the effectiveness of the vesicant.

(B) Clouds have no direct effect on any chemical agent. They attain their effects indirectly through their control over temperature which controls air currents. An overcast or cloudy day is less favorable for the development of rising air currents and, therefore more favorable to chemical attacks.

(C) Heavy rains in combination with high temperatures greatly reduce the persistency of mustard gas. Lewisite is readily hydrolyzed but forms a very toxic vesicant solid, L oxide, which is highly insoluble. Humidity and atmospheric pressure will have no appreciable effect on the persistent agents regardless of how they may be released.

(D) The terrain has no direct effect on the falling vesicant droplets other than any natural shelter afforded; it may attain some indirect effects through its limited control over local

temperature and wind conditions. However, after the vesicant droplets have fallen to the earth's surface, terrain conditions have a decided effect upon the effectiveness of the contaminated area (see Para. 3(D) below).

### 3. Effect of Weather and Terrain on Vesicant Vapor

(A) There may be sheltered or partly sheltered objectives where the vapor rather than the liquid chemical agent will produce most of the physiological effect. Under ordinary conditions four main factors cause dilution of the vesicant vapor. In order of their importance these factors are:

- (1) Lateral spread and vertical rise
- (2) Drag effect while traveling along earth's surface
- (3) Settling and adsorption
- (4) Destruction of the agent through hydrolysis

(B) Rates of dilution of the chemical agent as a vapor are affected by various weather factors. The following conditions are suitable for effective use of persistent vapor concentrations:

#### Favorable Conditions

Sky - Moderately to heavily overcast.

Time or day - Night or early morning.

Terrain - Level fields or water for vapor clouds moving in, and wooded areas for originating and holding vapor clouds. (The effectiveness of vapor clouds is not appreciably reduced by passage over water, but is greatly decreased by passage through a wooded area.)

Ground or water - Colder than air.

Winds - Calm or light winds free from strong convection

Temperature - Must be at least 5°F. above freezing point of chemical agent.

Visibility - Sufficiently good to see the target or reference point from the spraying height, unless other means of locating the target are possible.

(C) The following conditions render the persistent chemical agent as a vapor entirely or largely ineffective:

#### Unfavorable Conditions

Sky - Clear to cumulo-nimbus clouds.

Time of day - 1100 to 1600.

Terrain - Broken or wooded (for moving vapor clouds only).  
 (When the wind is calm or light, a wooded area is ideal for attaining a stationary, heavy, persistent vapor concentration. Since most of the aircraft spray droplets would be caught by the trees and bushes, the vapor concentration becomes important. However due to the high drag effect, vapor depositing on foliage, etc., movement of a vapor cloud in a wooded area greatly decreases the vapor concentration.)

Ground or water - Much hotter than air.

Winds - Strong winds and strong convection.

Temperature - **Less than 5°F.** above freezing point of chemical agent

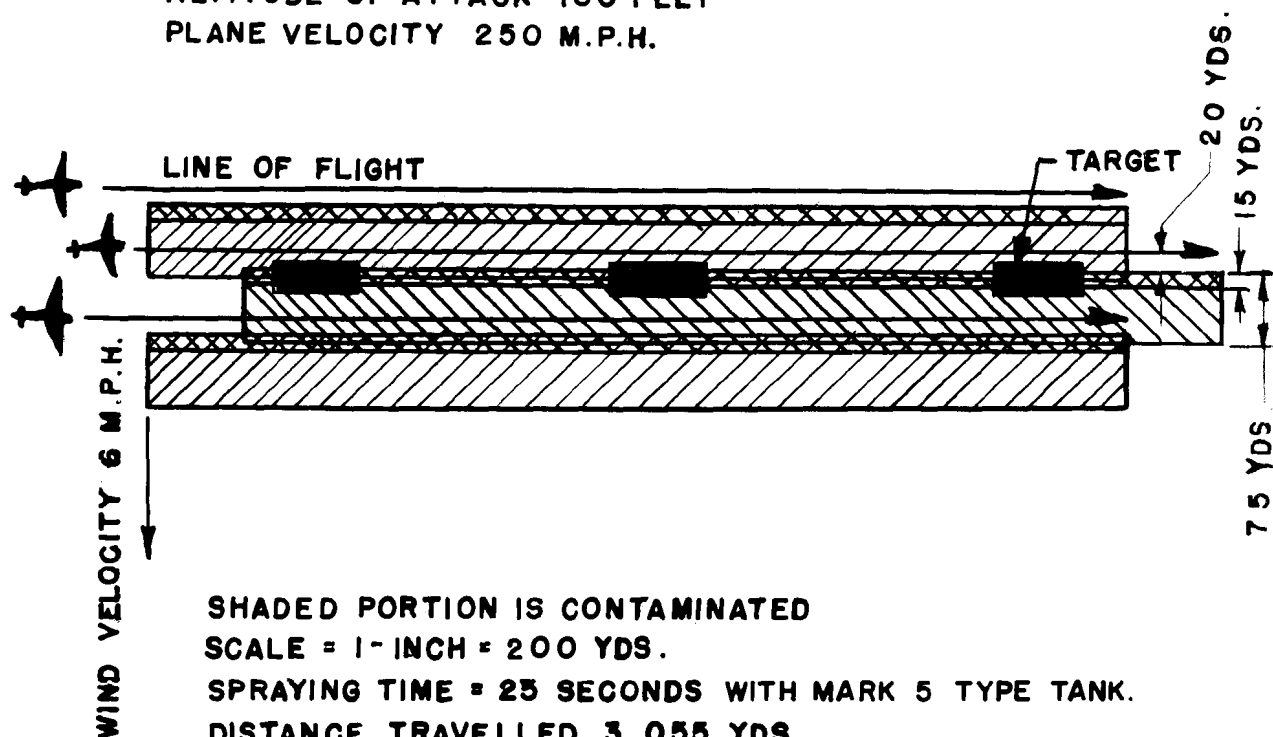
Visibility - **Insufficient** to allow accurate aiming when no means other than visual are available.

(D) It should be borne in mind that terrain areas contaminated by vesicant spray usually should not be relied upon to produce casualties for periods longer than that shown in the table below. Climatic conditions will cause a variation in this period of effectiveness. During cool weather the agent will retain its effectiveness for much longer periods than in hot dry weather. In any case, where a longer period of effectiveness is desired, repeated attacks may be made with vesicant spray, or the chemical bomb which is more persistent may be used. Terrain conditions have a decided effect upon the effectiveness of contaminated areas. Thus contaminated lightly wooded areas will produce more casualties than grassed areas; and contaminated grassed areas are more effective than areas of open ground. The following table shows estimated danger periods due to effective contamination by airplane chemical spray (H), assuming Service dress (not impregnated), average temperate weather conditions, and open country; add 50 to 200 per cent to the danger periods when in woods of varying density.

Traversing				Occupation	
Long grass (6 inches and over).	Medium grass (1 to 6 inches)	Short grass (under 1 inch)	Hard ground	Grass any length	Hard Ground
2 to 8 hours	2 to 3 hours	1 to 2 hours	1/2 to 1 hr.	24 hrs.	6 to 18 hours

Note: It is not practicable to undertake wholesale decontamination of large land areas sprayed with vesicant; such areas are usually marked and temporarily evacuated. A ship, on the other hand, can be decontaminated sufficiently in several hours by a well-trained decontaminating crew.

 DENOTES DROPLETS OVER 0.3 MG. IN SIZE  
 ALTITUDE OF ATTACK 100 FEET  
 PLANE VELOCITY 250 M.P.H.



SHADED PORTION IS CONTAMINATED  
 SCALE = 1-INCH = 200 YDS.  
 SPRAYING TIME = 25 SECONDS WITH MARK 5 TYPE TANK.  
 DISTANCE TRAVELLED 3,055 YDS.  
 INTERVAL BETWEEN PLANES = 60 TO 70 YDS.

(IDEALIZED EXAMPLE OF CONTAMINATED AREA AS READ FROM FIG. II)

FIGURE 8



DENOTES DROPLETS OVER 0.3 MG. IN SIZE  
ALTITUDE OF ATTACK = 500 FEET

PLANE VELOCITY 250 M.P.H.

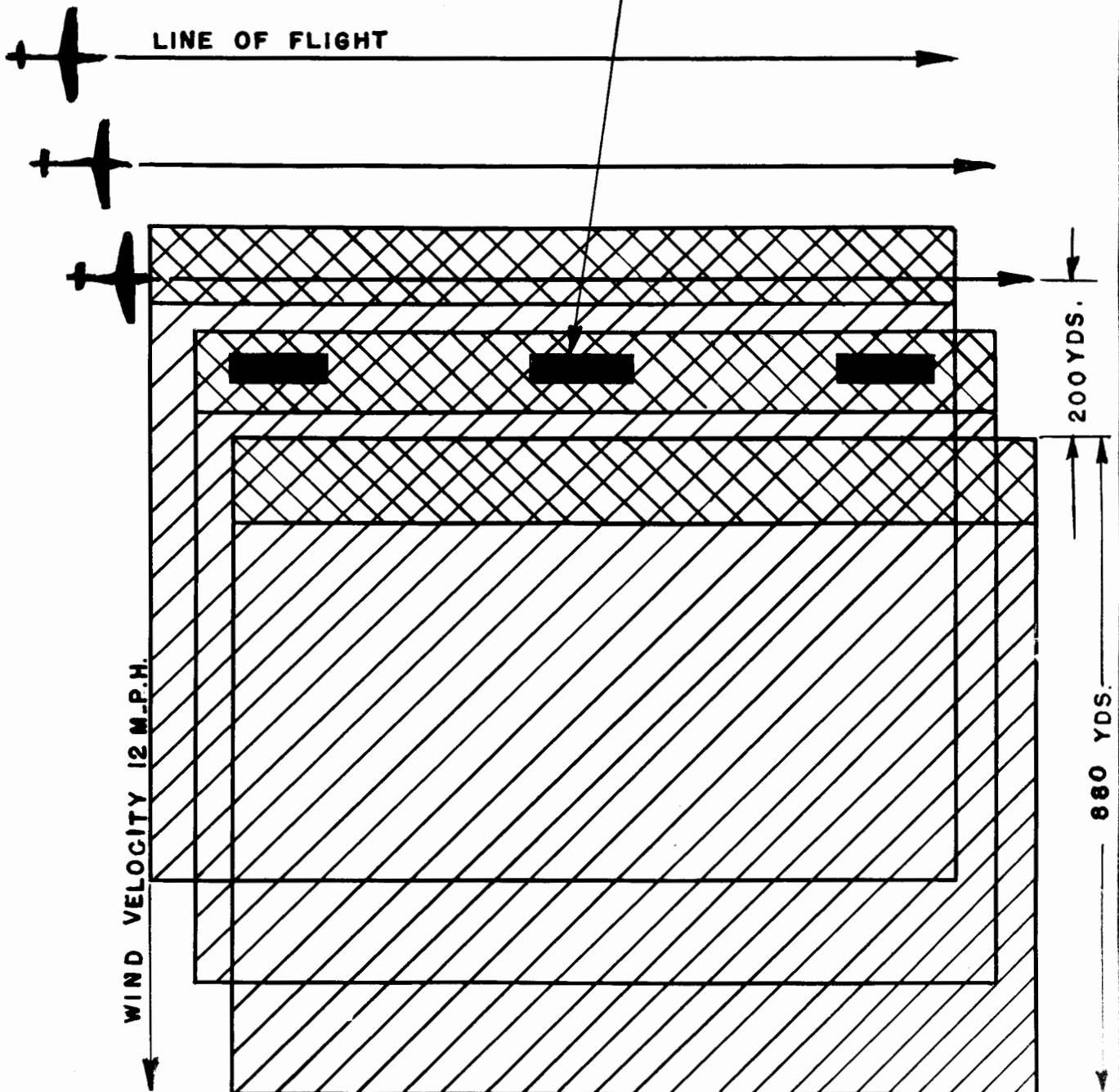
SHADED PORTION IS CONTAMINATED

SCALE = 1-INCH = 200 YDS.

SPRAYING TIME = 25 SECONDS WITH MARK 5 TYPE TANK

DISTANCE TRAVELLED 3,055 YDS. TARGET

INTERVAL BETWEEN PLANES = 135 TO 145 YDS.



IDEALIZED EXAMPLE OF CONTAMINATED AREA AS READ FROM FIG. 11

FIGURE 9

#### 4. Factors Affecting the Area and Degree of Contamination.

(A) Spray attacks may be delivered from low (500 feet or less); medium (500 feet to 4,000 feet;) or high (over 4,000 feet) altitudes. The greatest effect, for the effort involved, is usually obtained when spraying across the wind; increasing the acuteness of the angle of flight with the wind greatly lessens the area affected; however, it does increase the concentration and is preferred under certain conditions. Briefly, the shape of such areas will be as follows:

(1) When flying across wind, a rectangular-shaped area is contaminated, the heaviest contamination being near the upwind edge of the rectangle. When flying crosswind at high altitude, the downwind dimension becomes very large, the higher the plane and the stronger the wind the more pronounced this is (see Figures 8 and 9).

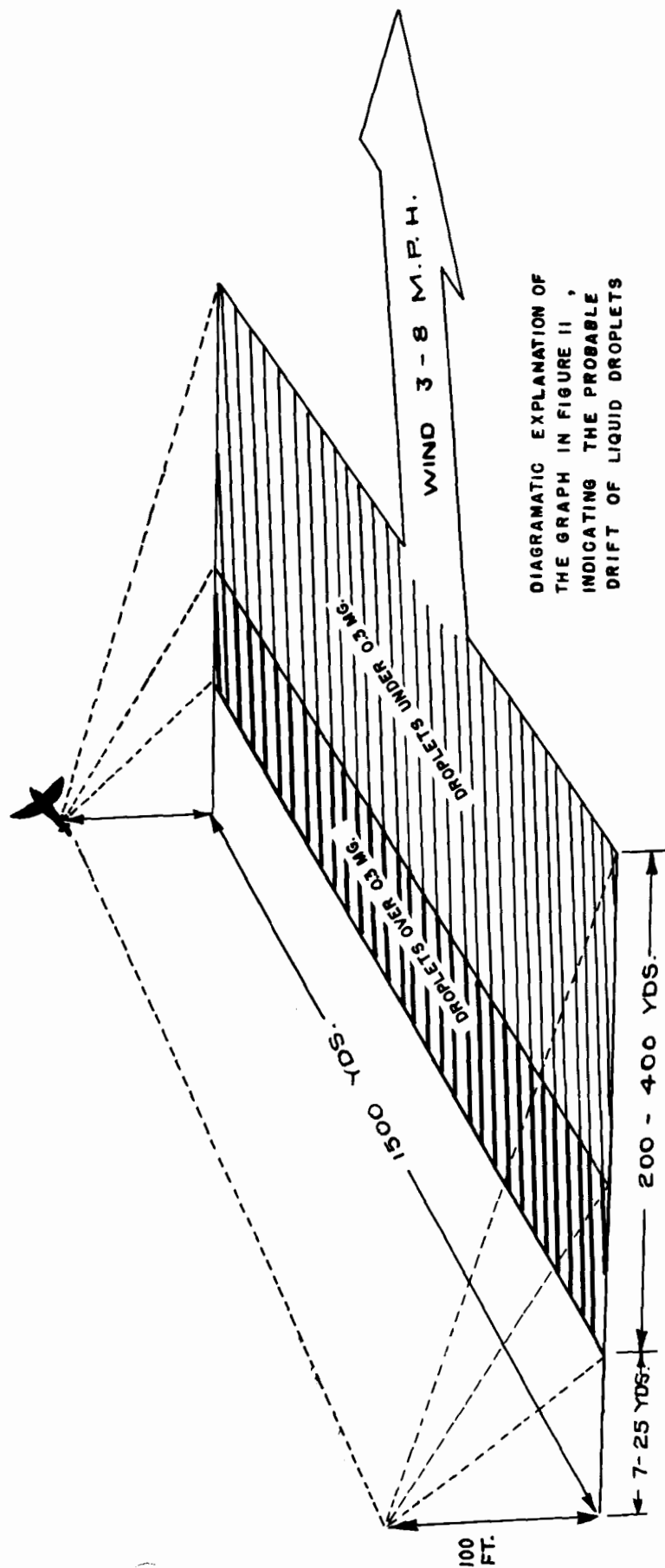
(2) Flying at an angle to the wind results in a diamond-shaped area (see Figure 12).

(3) In very low spraying, or low up or downwind spraying, the area is a narrow strip about 20 yards wide.

(B) The liquid chemical agent of medium (0.3 to 2.0 mg.) and large size (over 2.0 mg.) droplets rather than the vapor concentration is primarily relied upon for producing casualties, but vapor also plays an important part. Data indicate that practically all the breakup of the larger drops that occurs will take place in the first 200 feet. Assuming average conditions, the droplet size of aircraft chemical spray is one of the most important factors, for it largely determines the effectiveness of the spray, especially penetration and persistence. The terminal velocity of the largest drops (thickened agent) may be 30 feet per second (20 m.p.h.), while for the smallest drops (not vapor) less than 2 feet per second (1 m.p.h.). If the droplets are too small they drift too much, and even if they strike clothing on personnel the penetration may be negligible. Since all spray is composed of different size droplets with different terminal velocities, the spray constantly stretches out vertically as it falls. It also quickly attains horizontal movement with the wind; therefore, altitude and a crosswind directly impart width to the spray pattern on the ground, the droplets gradually decreasing in size downwind. The following factors determine the size and shape of the area contaminated, and the degree of contamination:

(1) The chemical agent and the size of the droplets.





DIAGRAMATIC EXPLANATION OF  
THE GRAPH IN FIGURE II,  
INDICATING THE PROBABLE  
DRIFT OF LIQUID DROPLETS

FIGURE 10

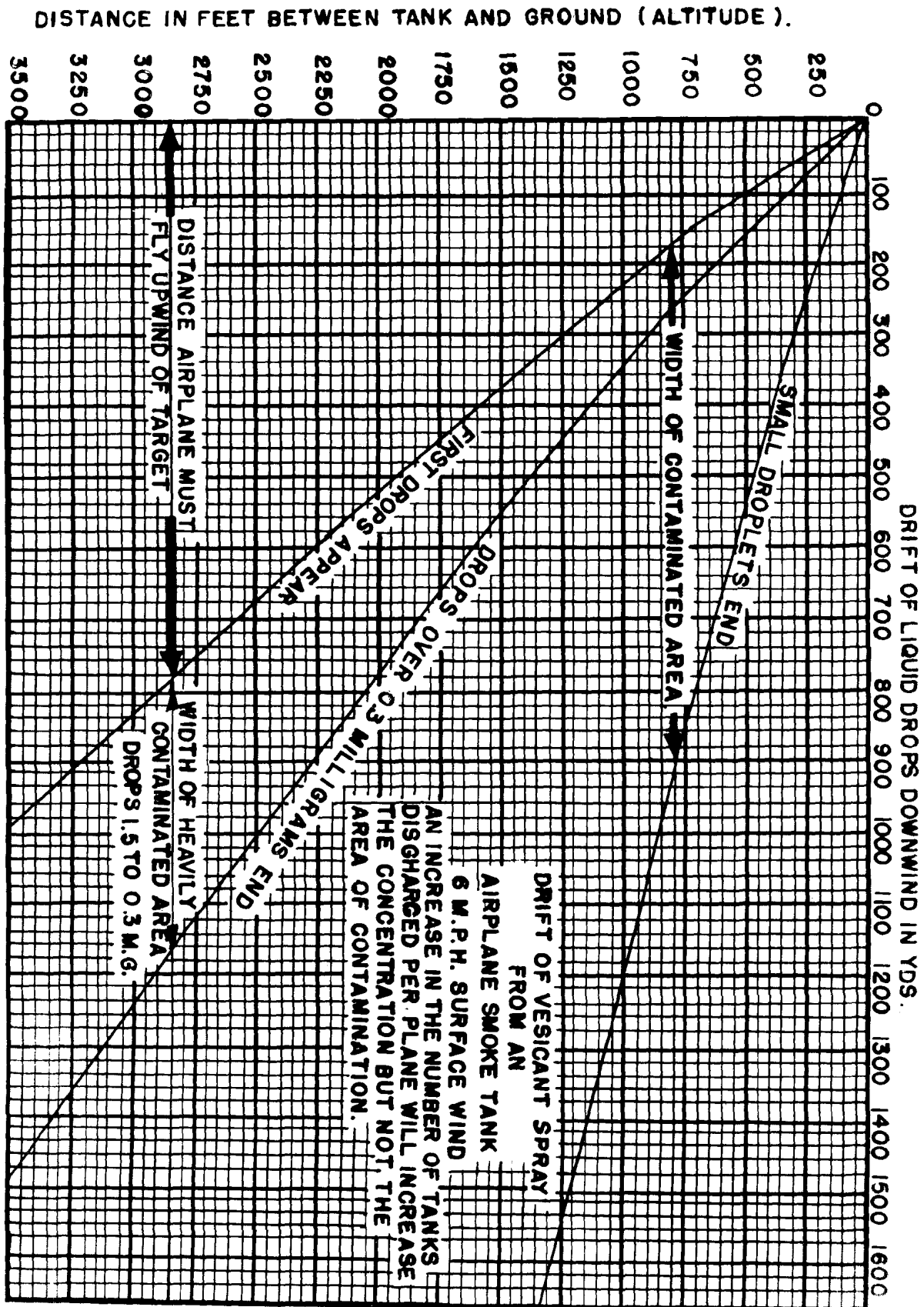


FIG. 11

EQUAL AREAS OF CONTAMINATION OBTAINED BY  
KEEPING EFFECTIVE CROSS WIND CONSTANT  
(FOR AREA SPRAYING ONLY)

LINE SHOWN AS DIAM. OF  
CIRCLE IS ACTUAL WIND  
VECTOR; OTHERS ARE  
COMPONENTS.

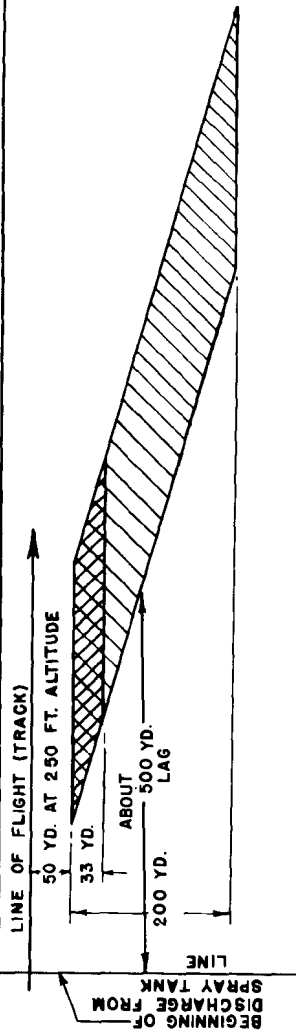
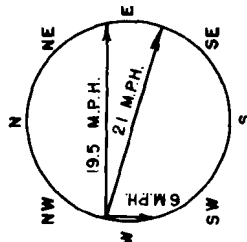
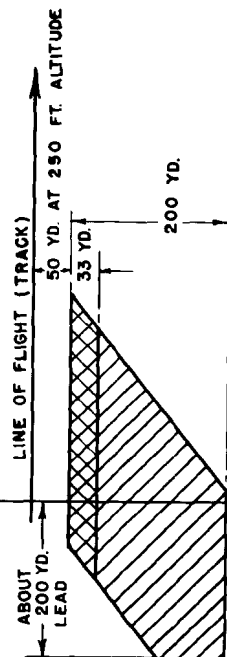
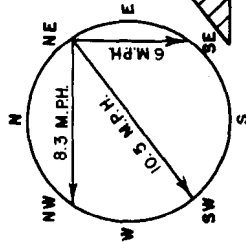
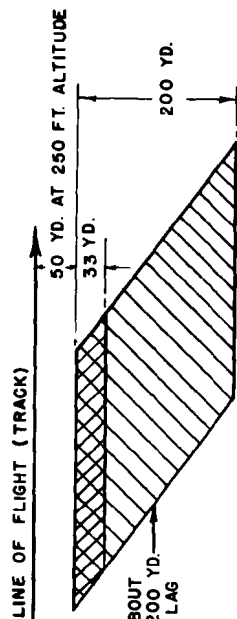
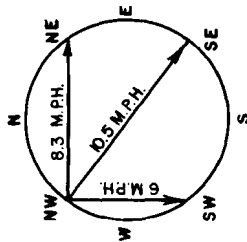
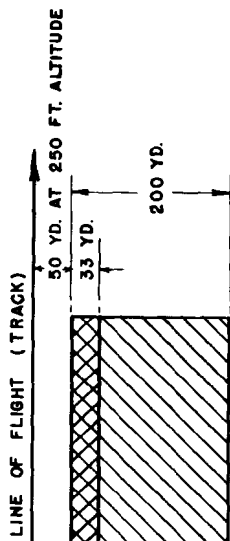
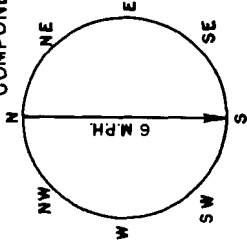


FIGURE 12

- (2) Type, size, rate of flow, and number of spray tanks.
- (3) Speed of the aircraft.
- (4) Course of the aircraft relative to the direction of the mean wind to the spraying altitude.
- (5) Height of the spraying aircraft.
- (6) Velocity of the wind, and other weather conditions.

Note: An increase in the rate of flow (or number of tanks discharged simultaneously) directly increases the degree of contamination, while an increase in the effective cross-wind or the speed or height of the spraying aircraft all directly decrease the degree of contamination. This relationship will be used later in setting up approximate formulas.

5. Technique of Vesicant Spraying. - The height at which spray is discharged will depend upon the accuracy required to place the chemical on the target, the amount of concentration desired on the target, and the size of the area to be covered. When spray is released at other than low altitudes, it will be difficult to predict accurately the area of fall, owing to the effect of varying winds through which the spray must descend. The graph, Figure 11, (see Figure 10 also) indicates the probable drift of the liquid droplets from an airplane when the line of flight (track) is approximately perpendicular to the direction of a 6 m.p.h. surface wind. This graph was made up using the average wind at the various heights when the surface wind was about 6 m.p.h.; hence, when the actual winds aloft are approximately known, the mean wind (vector) should be determined and used in its place (see Figure 12). The distance from the vertical coordinate to the line where the first drops appear gives the approximate distance the pilot should fly upwind of the target in order to hit the target effectively. The distance between the line where first drops appear and the line where small drops end gives the width of the contaminated area, which supplies vapor for a considerable distance downwind. The length of the area will depend upon the capacity and rate of flow of the smoke tank and the speed of the airplane. The effect of an increase or a decrease in the wind velocity is to transpose the curves in Figure 11 to the right or to the left, respectively, by changing the distances from the vertical coordinate to each curve a proportionate amount. An increase in

wind velocity, therefore, will directly increase the width of the contaminated area and decrease the concentration. Because of the excessive drift of the liquid at high wind velocities and consequent difficulty of hitting the target, vesicants will ordinarily not be sprayed in strong winds unless the altitude is very low. When the direction of approach is not a consideration, the mean cross wind may be kept at the optimum amount for a particular set of conditions. This may be accomplished by increasing the acuteness of the angle of flight with the mean wind and allowing in aiming the spray for the added lead or lag that is caused by the component of the wind along the line of flight (track) (see Figure 12). Figure 12 shows graphically how the line of flight (track) of the airplane can be altered with respect to the prevailing wind in order to obtain, with various winds, a cross component of 6 m.p.h. which is usually the optimum speed. As the altitude of spraying is increased, the concentration laid down from a unit source will decrease (the area increases), and it will therefore be necessary to discharge simultaneously a greater number of tanks or to decrease the area covered by decreasing the effective cross wind, in order to obtain the same effective persistent concentration. The spraying of the same quantity of liquid over a large area decreases the number of drops per unit area and as a result the length of time the vesicant will be effective will be decreased. By increasing the number of tanks discharged simultaneously, the same effective concentration can be obtained over the larger area. To obtain a more uniform coverage of the target area, individual airplanes or spraying units in a flight should fly a lateral distance apart less than the width of the contaminated area for the particular altitude that is to be used (see figures 8 and 9). The distance of drift of the spray at right angles to the line of flight (track) of the plane will be greatly altered if the wind is not at constant velocity and direction at various altitudes, and this is usually the case; hence, for greater accuracy the spraying airplanes should fly as low as conditions permit.

(A) In determining the number of airplanes required to effectively spray an area of a given size and shape, it will be necessary to know only the width and length of the effectively contaminated area produced by a single airplane and the location of the area with respect to the line of flight (track). The most uniform concentration is obtained by spacing individual airplanes laterally so that each spray pattern overlaps the next one, making small droplets in one pattern coincide with large droplets in the next one. However, rather than spacing individual airplanes, several airplanes may be grouped together, and considered as one. A regular tactical formation for the units that does not space the airplanes in a dangerous position with respect to the spray is the best formation for use when enemy air attack is probable.

For practical purposes the approximate center of each tactical spraying unit may be considered as the location of a single spraying airplane having a vesicant discharge rate equal to the total for that unit. So many factors influence the effectiveness of vesicant spray that nothing more than an estimate can be given for what constitutes an effective, casualty-producing concentration. This estimate can best be presented as a specific example from which formulas may be derived. The following conditions are estimated to produce an effective, casualty-producing concentration in temperate weather:

Altitude	(H)	250 feet
Speed	(S)	200 m.p.h.
Mean Cross wind	(V)	6 m.p.h.
Vesicant Discharge rate	(R)	10 gal./sec.

From the above data the following relation can be set up that will limit the variables to insure a desirable density:

$$\frac{R}{HVS} = \frac{(10)}{(250)(6)(200)} = \frac{1}{30,000} = \text{density constant.}$$

$$HV = \frac{30,000 R}{S}$$

Nothing has been said about the drop size of the spray (see Figure 13) in connection with the effective concentration, because with a given range of drop sizes, this is a matter of locating and spacing the airplanes laterally so that the spray patterns overlap and always contain droplets over 0.3 mg. in size. The total amount of vesicant required for a given degree of persistency or penetration of clothing increases as the drop size decreases, and this size (0.3 mg.) is selected as the minimum size for practical efficiency. If the spray patterns overlap so that the slow falling 0.3 mg. droplets from each airplane (airplanes flying side by side) coincide with the fast falling 3 mg. droplets from each succeeding airplane (downwind), then the sprayed area will always contain droplets over 0.3 mg. in weight. Since both 3 mg. and 0.3 mg. droplets will nearly always be present, regardless of the kind of tank, in high or low altitude spraying, using thickened or unthickened vesicant, the spread on the earth's surface between these two drop sizes will be taken as the approximate width, measured perpendicular to the airplane's path over the earth's surface, contaminated by droplets over 0.3 mg. in size. Maximum drop sizes of either 1 mg. or 9 mg., instead of 3 mg., would produce the same absolute error in this width, because the absolute difference in terminal velocity between the 3 mg. and 1 mg. drops is the same as that between the 3 mg. and 9 mg. drops. This error in width, however, would be only about  $\pm 10\%$ ; a negligible amount compared to the errors caused by wind variations. The width (w) in yards of the strip containing droplets over 0.3 mg. in weight is found as follows:

.05 .01 .02 .03 .04 .05 .06 .07 .08 .09 10 30 50 60 90

AIRCRAFT SPRAY, USING MOLASSES RESIDUUM  
(MR), AND GAGE FOR DROP SIZE IN MILLIGRAMS  
ON STANDARD 110# BRISTOL BOARD

FIGURE 13

Approx. terminal velocity of 0.3 mg. droplets = 9 ft./sec.  
 Approx. terminal velocity of 3 mg. droplets = 22 ft./sec.

$$\frac{H}{9} (1/2 V) = \text{drift of 0.3 mg. droplets in yards (V multiplied by } \frac{1}{2} \text{ to convert from m.p.h. to yds./sec.)}$$

$$\frac{H}{22} (1/2 V) = \text{drift of 3 mg. droplets in yards.}$$

$$w' = \left( \frac{H}{9} - \frac{H}{22} \right) 1/2 V = \frac{HV}{30} . \text{ Therefore } HV = 30 w' \text{ based on drop size,}$$

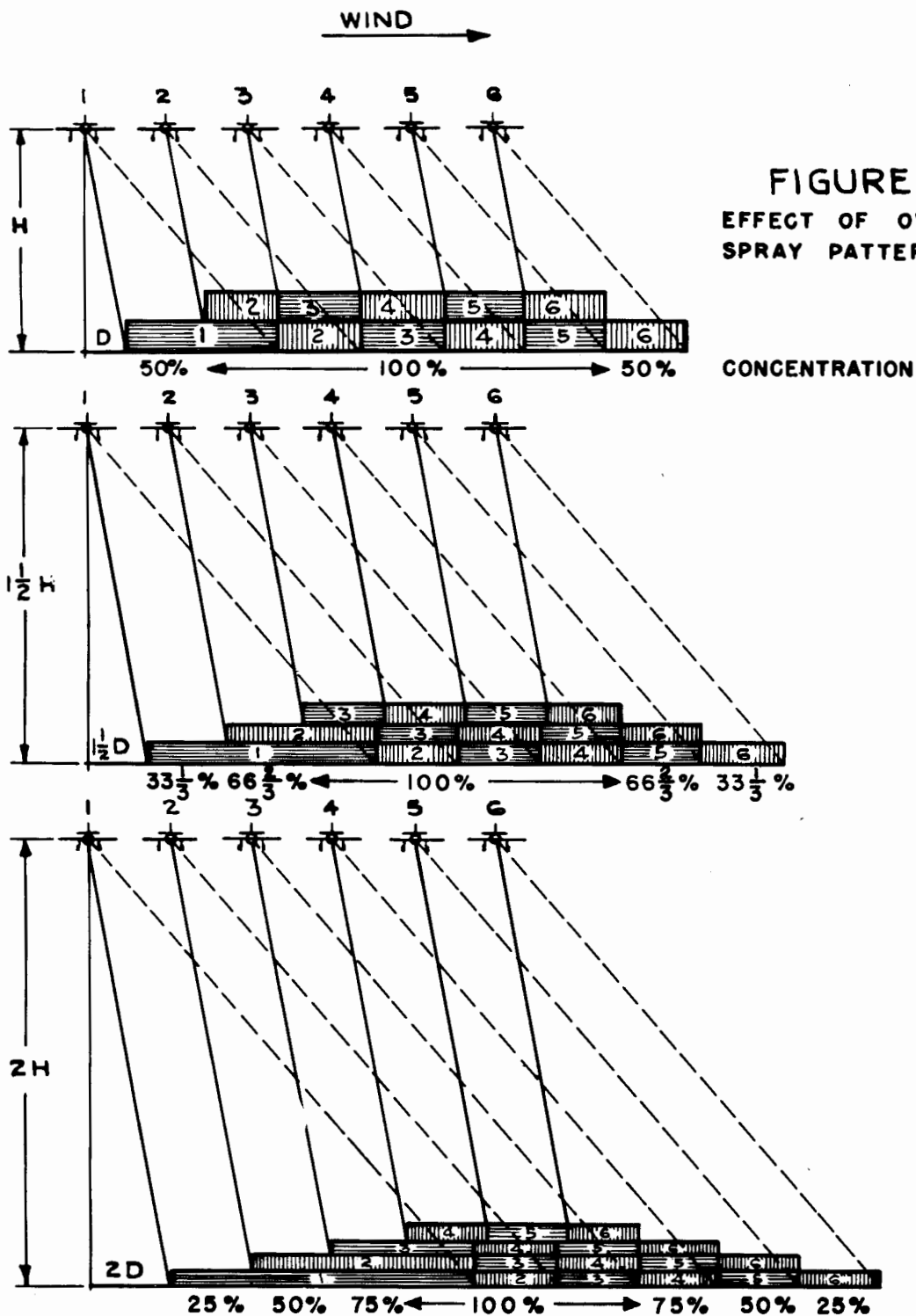
and  $HV = \frac{30,000 R}{S}$  based on density. From both equations we have

$$30 w = \frac{30,000 R}{S}, \text{ or } w = \frac{1000 R}{S} \text{ based on both drop size and density}$$

requirements, where  $w$  is the one particular value of  $w'$  when  $H = \frac{30 w}{V}$ . It is recommended that at least two or three air-

planes be considered as the basic or minimum spraying unit since overlapping spray patterns (see Figure 14) not only hold the inside strips to a more uniform, constant density over a wide variation in altitude and wind velocity (depending on number of airplanes), but also increases the total width effectively contaminated and thereby adds to the chance of hitting the target. Symbols will be defined and used directly in approximate formulas based on the above data for an effective, casualty-producing concentration in temperate weather. These formulas will be found helpful in making charts or tables for use on specific spraying missions. It is emphasized that variations in other factors, too numerous and impracticable to include in these formulas, make the final computations nothing but the estimated requirements for effective contamination in temperate weather by falling droplets 0.3 mg. or more in weight. The fact must not be overlooked that about twice as much vesicant will be needed in cool weather and only about one-half as much in warm weather. Although the formulas are based on that part of the spray (falling droplets) most generally relied on for physiological effect, the droplets smaller than 0.3 mg. and the vapor concentration may have considerable effect, but this depends heavily upon factors too hard to estimate accurately and too numerous to incorporate into simple formulas. It is intended that the requirements set up by the formulas also be taken as the standard for aircraft vesicant spray in estimating the vapor effect from the information given in paragraph 3 of this chapter. Although casualties may be caused by contact with (1) falling droplets, (2) vapor, and (3) contaminated objects, when





**FIGURE -14**  
EFFECT OF OVERLAPPING  
SPRAY PATTERNS

RECTANGLES INDICATE WIDTH AND CONCENTRATION OF CONTAMINATED AREA.  
THE DISTRIBUTION OF SPRAYED MATERIAL VARIES DIRECTLY WITH ALTITUDE  
OF THE PLANE OR VELOCITY OF CROSS WIND, EXAMPLE - IF EITHER  
ALTITUDE OF THE PLANE OR VELOCITY OF CROSS WIND IS DOUBLED,  
THE RESULT WILL BE IDENTICAL, THAT IS, TWICE THE AREA WILL BE  
COVERED AT ONE-HALF THE CONCENTRATION.

reliance is placed principally on (1), (2) and (3) may be considered as safety factors and, of course, when (2) and (3) are wholly depended upon for producing casualties or denying areas, etc., (1) is simply the source of (2) and (3). Reasonable estimates are necessary for intelligently planning an effective aircraft vesicant spray attack, and the following formulas, plus a knowledge of the important factors not included in these formulas will furnish the basis for these necessary estimates.

- R = Vesicant discharge rate per plane in gallons per second (total rate for all spray tanks on the airplane, if operated simultaneously).
- S = Ground speed in miles per hour or, for practical purposes, the indicated airspeed if the difference is relatively small.
- L = Length in yards covered by one pass. An ample safety factor should be provided for any lag or lead in the falling spray.
- T = Time of vesicant discharge in seconds for one pass.
- w = Width in yards (measured perpendicular to the track over the ground) contaminated with droplets over 0.3 mg. by one airplane flying at the required altitude for just producing the desired density.
- W = Total width in yards (measured perpendicular to the track over the ground) that should be contaminated in order to cover, with an ample safety factor, the width of the target area.
- N = Number of airplanes required for one pass to effectively contaminate the area of width W and length L.
- H = Any practicable height in feet within the upper and lower altitude limits for a specific set of conditions.
- Note: Before selecting definite altitudes, it will be necessary to determine the lowest possible altitude that still permits completely covering the target area, and the highest possible altitude for still obtaining an effective concentration.
- I = Interval (lateral) in yards between individual airplanes or if using tactical spraying units, between spraying units of airplanes for keeping the spray uniform and within the target area at the selected height.
- G = Number of airplanes in one tactical spraying unit.

V = Mean wind velocity (vector) in miles per hour to height H, measured at right angles to the track over the ground.

Note: It is pointed out that V is the most unreliable factor. Even when very accurate measurements of the mean wind (vector) are made only 30 minutes or so before actually spraying, it will in all probability have changed slightly during the 30 minutes interval. The higher the airplanes the more effect such variations will have; hence, low altitude spraying is considerably more accurate than high altitude spraying.

D = Distance (lateral) in yards that upwind airplane (or tactical formation unit of airplanes) should fly from the upwind edge of target area for the selected altitude in order to hit the target; specifically, the approximate lateral drift of the 2 mg. droplets (terminal velocity about 20 ft./sec.). The 2 mg. droplets were chosen because it is better to spray too far upwind than not far enough.

$$(1) \quad w = \frac{1000R}{S}$$

(Width effectively covered by one plane in temperate weather).

$$(2) \quad L = \frac{TS}{2}; \quad T = \frac{2L}{S}$$

(Length (L) covered by one plane or discharge time (T) for intermittent spraying)

$$(3) \quad N = \frac{W}{w}$$

(Number of planes required)

$$(4) \quad H = \frac{30 \quad Gw}{V}$$

(The upper and lower limits of H will depend on the values assigned to G; therefore, for the lower limit substitute the selected value of G and for the upper limit substitute  $G=N$ . Any value of H within these two limits may be used in formula (5) below.)

$$(5) \quad I = Gw \left( \frac{W - \frac{HV}{30}}{(W - Gw)} \right)$$

(Interval for producing uniform contamination and keeping all the spray within the target area).

$$(6) \quad D = \frac{HV}{40}$$

(Upwind lateral distance that windward unit should fly from edge of target area)

<u>Spray Tank</u>
Mark 7 type
Mark 5 type
M-10 type
M-33 type

<u>Discharge Time</u>
14 seconds*
23 seconds**
6 seconds
7 seconds

<u>Discharge Rate</u>
1.3 gal./sec.
2.0 gal./sec.
5 gal./sec.
10 gal./sec.

\*Discharge time given is for the average rate of flow.  
This tank is capable of intermittent spraying.

\*\*Discharge time given is for the approximate maximum rate of flow. The rate of flow can be decreased and the tank is capable of intermittent spraying.

The following problem will be briefly worked out, using Mark 5 type tanks, to illustrate use of the formulas.

Given:  $R = 4 \text{ gal./sec. (2 Mark 5 tanks per plane)}$

$S = 200 \text{ m.p.h.}$

$V = 6 \text{ m.p.h.}$

It is assumed that the wind relative to an irregularly shaped target is such that the target can be approached from a certain direction and the target area can be enclosed by a square, 1000 by 1000 yds., such that the area  $(W)(L)$ , includes the necessary safety margins. This area should be increased as the spraying height increases to allow for errors due to wind variations. It is further assumed that enemy air attack is probable and that machine gun fire from the ground is likely, hence, "H" will be selected as 3000 ft. (if possible) and "G" as 5.

$$(1) w = \frac{1000R}{S} = \frac{(1000)(4)}{200} = 20 \text{ yards}$$

$$(2) T = \frac{2L}{S} = \frac{(2)(1000)}{200} = 10 \text{ seconds.}$$

$$(3) N = \frac{W}{w} = \frac{1000}{20} = 50 \text{ airplanes.}$$

$$(4) H = \frac{30Gw}{V} = \frac{(30)(5)(20)}{6} = 500 \text{ feet (lower limit);}$$

$$H = \frac{(30)(50)(20)}{6} = 5000 \text{ ft. (upper limit).}$$

$$(5) I = Gw \left\{ \frac{W - \frac{HV}{30}}{W - Gw} \right\} = (5)(20) \left\{ \frac{(3000)(6)}{1000 - (5)(20)} \right\} = 44 \text{ yards.}$$

$$(6) D = \frac{HV}{40} = \frac{(3000)(6)}{40} = 450 \text{ yards.}$$

From the above information the path over the ground for each of the ten tactical spraying units of 5 planes each can be laid out. The farthest upwind unit should fly 450 yards from the upwind edge of the target area, and each succeeding unit should be spaced laterally (downwind) from this line at intervals of 44 yards. Since the above conditions are the estimated requirements for causing all the

effective spray from 3000 ft. to fall within the target area, the effect of errors in any one of these conditions should be examined so that the flight plans may include more flexibility in certain directions. A check should be made to verify that the area, (W)(L), is sufficient to allow for estimated errors. Alternate altitudes, etc. may be conveniently included in the plans by also supplying this information on any marked maps, tables, or charts that are being provided for guidance of the pilots. In this example only 10 seconds of actual spraying is required; therefore, by making use of the intermittent spraying feature of the Mk. 5 type tanks, the required area may be effectively contaminated by making two passes (spraying 10 seconds each pass) with only half the number of airplanes. One-half the area should be completely contaminated by each pass. No standard methods will fit all circumstances; it will be necessary to work out tactics and technique believed best for particular conditions.

(1) It will be difficult during actual operations to ascertain and compensate for wind conditions at the target, so when flying low and relying on accuracy to hit particular targets (not area spraying), the flight path should conform to the path of the target. However, when flying low and approximately crosswind and it is evident that there is a strong wind across a line of targets, the flight path of the airplanes should favor the upwind side of the targets, and to insure at least a partial hit on a long line of targets, the flight and target lines should gradually converge.

(2) For Navy type tanks the lag between the first movement of the discharge lanyard and the start of spraying may be about one second. A similar lag may be expected in the operation of Army type tanks. If a one second lag is not taken into account, a plane flying 175 to 350 knots (200 to 400 m.p.h.) could easily overshoot the intended starting point by 100 to 200 yards. It is therefore desirable to lead the target sufficiently to provide a safety factor and to allow for a time lag. Also when flying other than crosswind, the component of the wind along the line of flight will cause a lag (drift of the spray in the direction of flight) or a lead (drift of the spray in the opposite direction), which should be taken into account (see Figure 12).

(3) In order to obtain the heaviest vesicant concentration the Mark 5 type smoke tank should be operated using the greatest regulator pressure obtainable (about 200 pounds per square inch). For more detail see Chapter 4. A lower discharge flow rate may be satisfactory for laying smoke screens, but it is necessary to use the full rate of discharge when spraying vesicants in order to obtain the most effective field concentration within the capabilities of the tank.

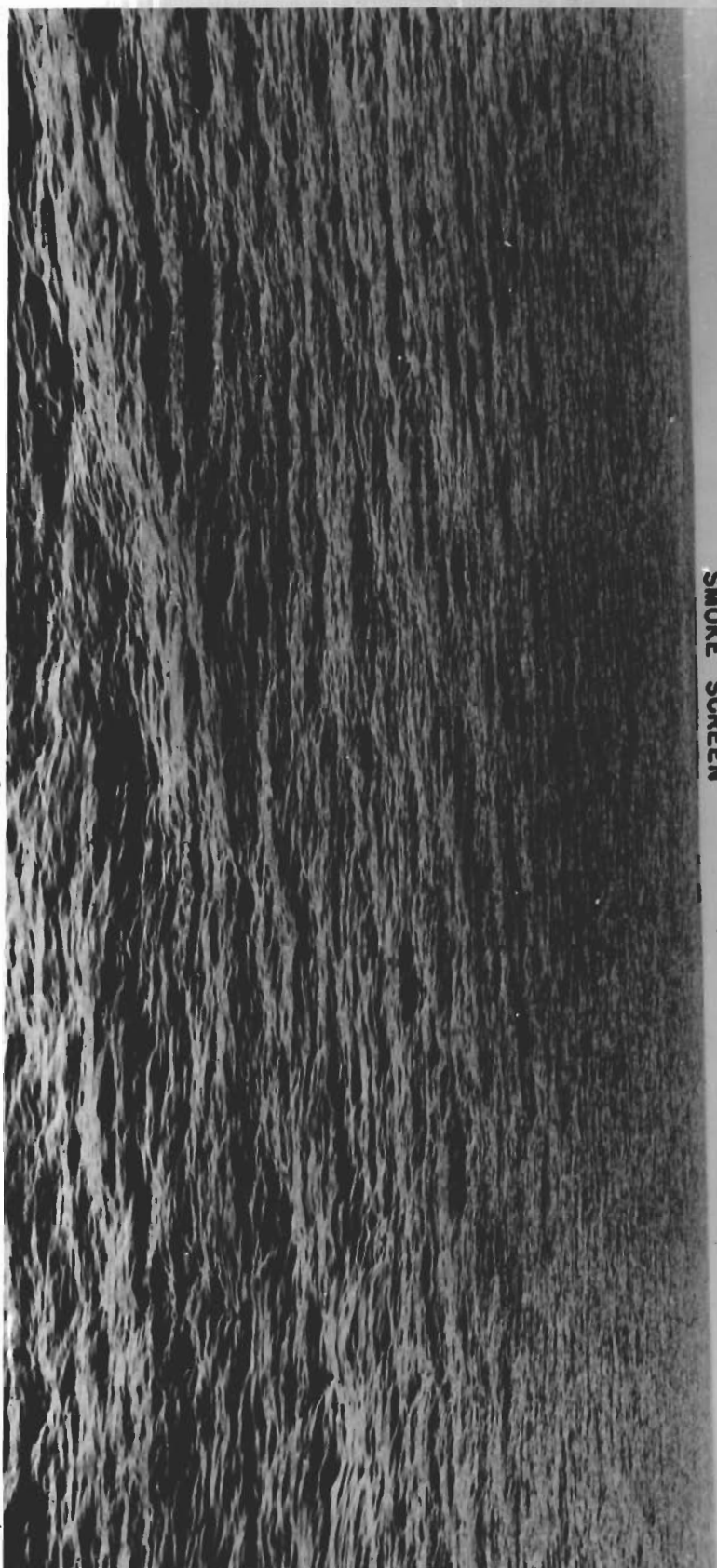
- (4) Personnel of the spraying aircraft should be provided with gas masks, protective clothing, first aid and decontaminating material, etc. for use in emergencies.
- (5) It should be remembered that the Mark 5 type tank (pressure type is unsafe for use if punctured, because the airplane may be contaminated by any vesicant ejected by CO<sub>2</sub> pressure through the holes. If an airplane becomes engaged in aerial combat, the tanks should be jettisoned immediately, noting the exact location where dropped if over friendly land, in order that steps can be taken to have the contaminated areas located and decontaminated. If a tank is dropped from a sufficiently high altitude, it will burst upon impact and produce an effect similar to that of a large thin case chemical bomb.
- (6) Special care should be taken to avoid flying through any vesicant spray. On the ground and in the air an airplane carrying spray tanks should not be followed immediately in trail by other airplanes. However, usually more than one plane is required to lay down a desired concentration in a given area; the planes should follow closely behind one another but well stepped up toward the rear and over a distance to windward depending on particular conditions. It is pointed out that downward accelerations of the airplane may cause the spray to strike the tail surfaces; hence, diving or stalling maneuvers should be avoided while actually spraying.
- (7) After discharging any chemical agent, further flying for 15 to 30 minutes will minimize or prevent any dripping from the spray tank discharge line.

## 6. Technique of Laying Smoke Screens

- (A) The only requirements of a smoke screen are that the screen be long enough to encompass the target and properly placed to prevent lateral observation (see Figures 5 and 15). In this method, a wall of smoke is formed by laying the smoke from an altitude of about 125 feet for FS or 140 feet for FM. Not only do the screens fall to the earth's surface, but the tops of both screens rise to an altitude of approximately 250 feet in about 15 seconds; the FS screen showing less tendency to break up than the FM screen. The base of a single FS screen will be approximately 300 feet thick and the base of an FM screen about 125 feet thick.
- (B) The Naval Proving Ground found that, when using FS, a density of 10 gallons per thousand yards gave an excellent screen if the screen was laid up or down wind, and the force of the wind did not exceed 14 knots (16 m.p.h.). If the screen is made across wind under the same wind conditions, densities of 13 gallons and 15 gallons per thousand yards both appeared

FIGURE 15

SMOKE SCREEN



to make a satisfactory screen. Densities of approximately 20 gallons per thousand yards gave good screens under gusty wind conditions where the wind velocity exceeded 20 knots (23 m.p.h.). The above remarks apply to screens made using a single airplane and one Mark 5 type smoke tank. The fleet may find that excellent screens are obtained with less densities or that several airplanes flying in echelon, each laying at a fraction of the desired density, will give a more efficient screen.

(C) Since a flow rate of .0005 gal./sec. is approximately equal to 1 gal./1000 yds./m.p.h., the following formula may be conveniently used to compute the flow rate (in gal./sec.) required to obtain the desired density in gal./1000 yds. for a specific speed.

Flow rate (in gal./sec.) = gal./1000 yds. X m.p.h. X .0005

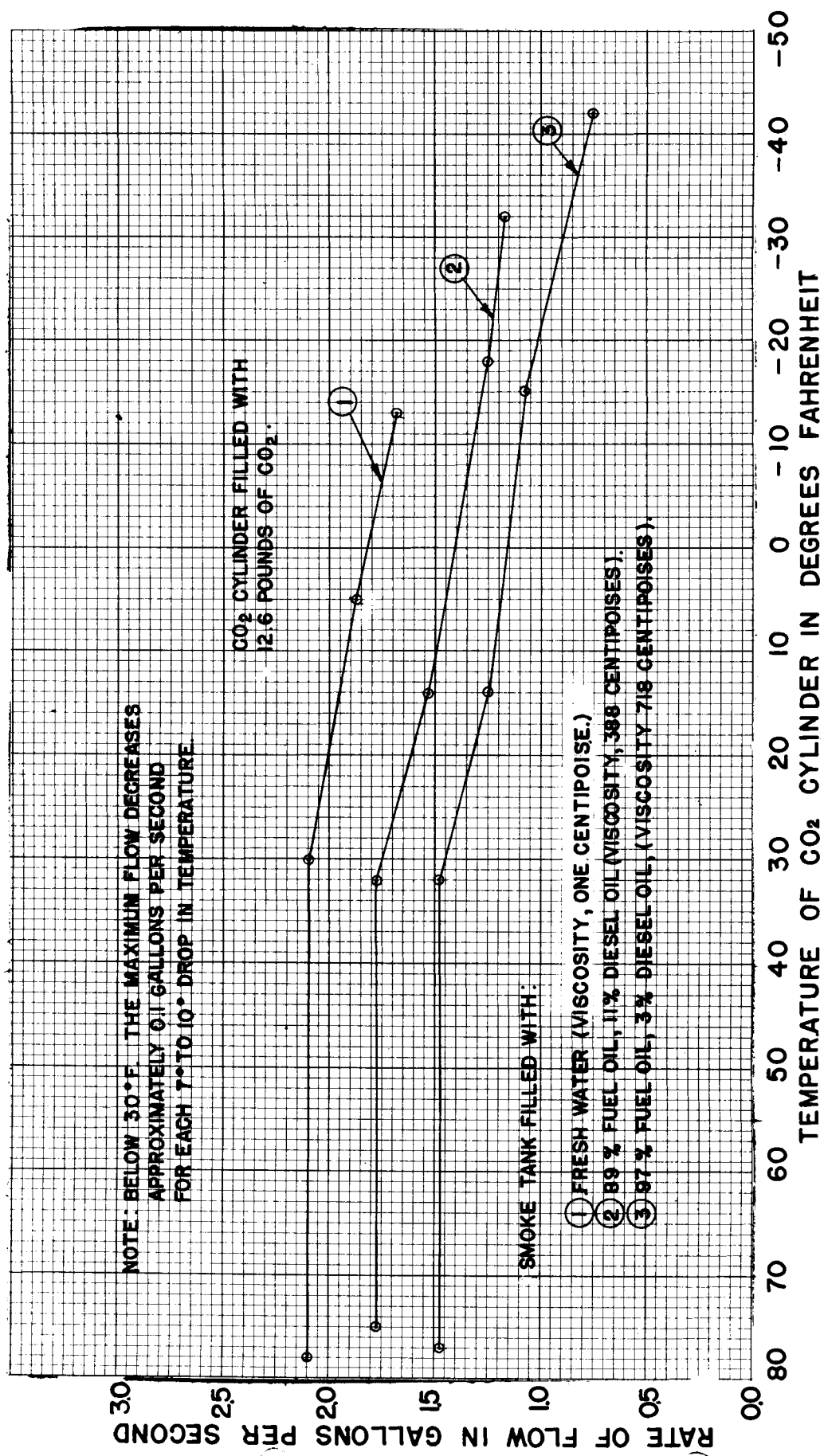
For example if flying 225 m.p.h., and it is desired to lay a smoke screen having an approximate density of 13 gal./1000 yds.,  $13 \times 225 \times .0005 = 1.46$  gal. sec. For operation of the Mark 5 type tank, refer to Figure 22, and it will be seen that approximately 147 pounds per square inch regulator pressure is required to maintain a flow rate of 1.46 gal./sec.

(D) Smoke clouds usually persist for about 15 to 20 minutes, the behavior and duration depending on the initial smoke density and on the factors of weather and terrain, the effect being similar to that given for vesicant vapor clouds in paragraph 3 of this chapter. The cloud will maintain its density for a considerable time in a steady wind of moderate velocity, but may soon be dispersed by a strong or gusty wind. A single line of smoke will usually provide a satisfactory screening effect while drifting from 3,000 to 4,000 yards from the original line in steady winds from about 2 to 25 m.p.h. velocity. The leading edge (top) of the cloud usually travels approximately 1-1/2 times as fast as the surface wind because the velocity of the wind is usually greater at an altitude of 100 or 200 feet than at the surface, and the trailing edge, being retarded by contact with the surface, moves at approximately 8/10 of the wind velocity. Computation of the probable drift and spread of a smoke cloud can be based on the figures given above.

#### Low Temperature Operation

(A) Smoke screens cannot be produced in temperatures below the freezing point of the smoke mixture, and screening operations in cold weather will require more smoke material because the absolute moisture content of the air normally decreases with the temperature. In extremely cold weather FM smoke screens are superior to FS smoke screens.





MAXIMUM RATE OF FLOW VS TEMPERATURE FOR A MARK 5 TYPE  
SMOKE SCREEN TANK FILLED WITH LIQUIDS OF DIFFERENT VISCOSITY

FIGURE 16

(B) Vesicant spraying and smoke screen operations in cold weather, when possible, simply require more material, but vesicant spraying requires more consideration because the effect of cold weather is more pronounced.

(1) The effectiveness of vesicant agents decreases with the temperature; the added protection of heavy winter clothing further decreases the probability of contaminating personnel.

(2) The rate of flow of spray tanks decreases due to the increase in viscosity of the chemical agent in cold weather (see Figure 16). The CO<sub>2</sub> cylinders used with pressure type tanks lost pressure and the flow of CO<sub>2</sub> vapor decreases more rapidly in cold weather because less heat is available for vaporization of the liquid CO<sub>2</sub>.

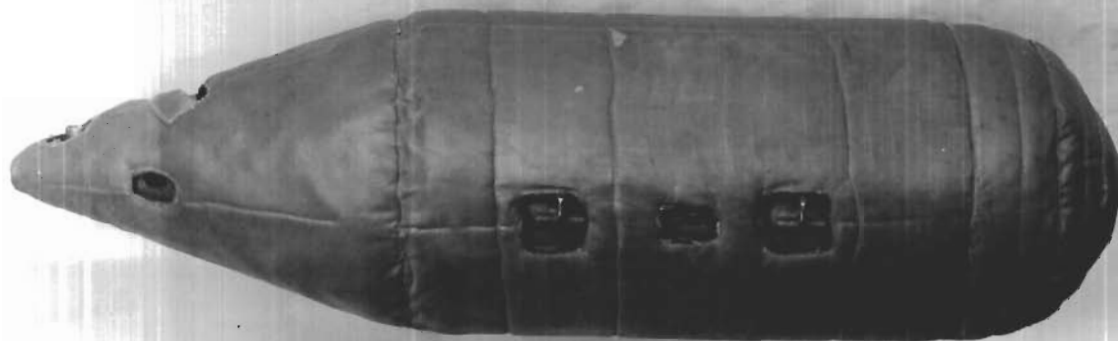
(3) The temperature may be so low as to freeze the vesicant, thereby preventing discharge from the tank. Since mustard gas (commercial product) freezes at about 48°F, its use requires more consideration than the other agents.


(C) The disadvantages in (1) and (2) above can be offset only by spraying much larger quantities of chemical agent, i.e., using more airplanes and spray tanks. The use of freezing deterrents for H is covered in Chapter 2 on Chemical Agents.

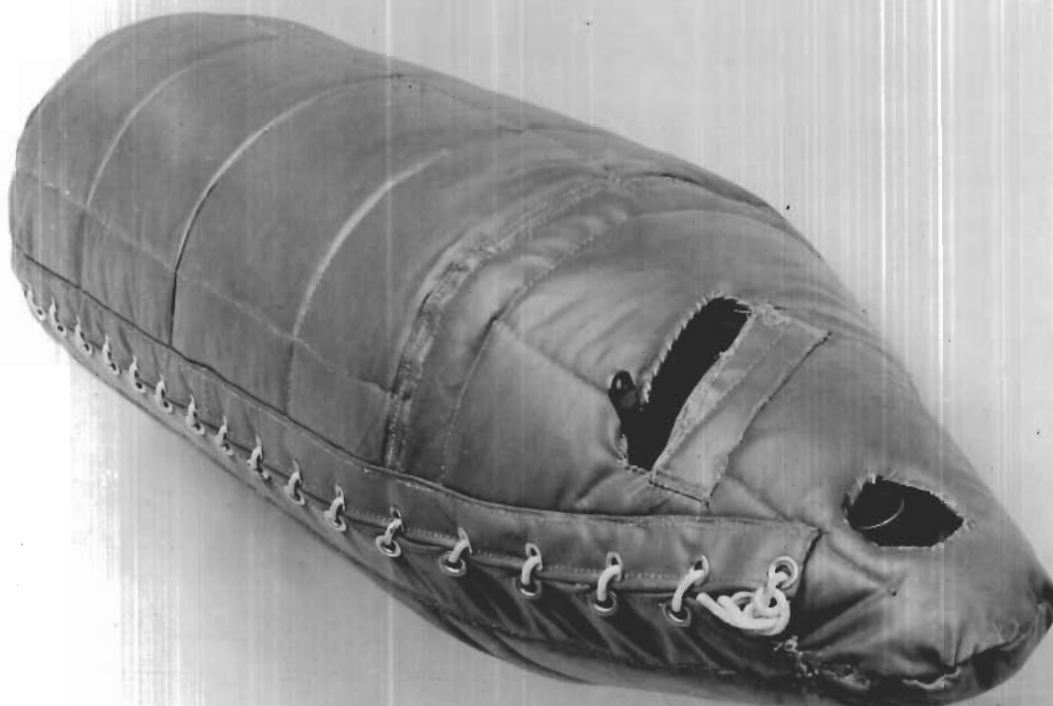
(1) If H filled spray tanks are to be subjected to extreme cold for several hours, such as that encountered at high altitudes, insulating the tanks with lagging will keep the H from freezing for several hours (depending considerably on initial temperature of filled tanks) and permit discharging the H any time during this interval. The filled tanks may be heated (not over 110°F) before installing the insulating cover. If the surface temperature is below the vesicant freezing point, the chemical agent will freeze after discharge, limiting its use to harassing the enemy or denying areas to the enemy. However a potential, effective, casualty-producing concentration could also exist, requiring only that the temperature rise sufficiently.

(2) The formation of a crust (frozen H) on the inside walls of a container due to the rapid loss of heat by the liquid in contact with metal, provides insulation, but this condition in the Mark 5 type smoke tank might seriously restrict the flow because of the small clearance between the end of the discharge pipe and the walls of the tank.

(3) If no lagging is available, keeping the tanks warm before installation and holding exposure to the cold ambient air to a minimum will help considerably in preventing the mustard from freezing before discharge. Thus high altitudes, where freezing temperatures might be encountered, should be avoided.



CHEMICAL  
WARFARE  
SERVICE  10283



CHEMICAL  
WARFARE  
SERVICE  10230

MARK 5 TYPE TANK WITH INSULATING COVER

FIGURE 17



CHEMICAL  
WARFARE  
SERVICE

RESEARCH

10194

M10 SPRAY TANK WITH  
INSULATING COVER.

FIGURE 18

(D) Although vapor concentrations are greatly decreased by cold weather, the fact that the persistency increases makes cold weather ideal for preventing normal occupation of areas and contaminating equipment, etc. The danger in this case is not from the vapor, but from contact with any objects contaminated by the vesicant. A large land area heavily contaminated may remain dangerous all winter, and complete decontamination would be impossible, or at least a very laborious and impractical process. This fact should be kept in mind if friendly troops are expected to occupy the area before the arrival of the warmer season.

*1 July 1943*

## Chapter 4

### Mark 5 Mods 2 and 3 Smoke Screen Tanks

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3.	Operation	55
4.	Operating Procedure	57
5.	Stock Numbers	61

1. Description - The Mark 5 Mods 2 and 3 Smoke Screen Tanks are bomb-shaped, monel tanks used for spraying liquid chemical agents from an airplane. The Mark 5 Mod 3 Smoke Screen Tank is identical in all respects to the Mark 5 Mod 2 Smoke Screen Tank, except that the two filling plugs located topside on Mark 5 Mod 2 tank have been replaced by one drainage plug located in the nose of the tank. This change was made, since in some installations, the filling plugs projected above the tank far enough to cause interference, which prevented the tank from being suspended without making alterations. The Mark 5 type tanks are approximately 67 inches long, 19 inches in diameter, and have a capacity of 51.2 gallons (no void). The weight of the tank is 184 pounds when empty. The Mark 5 type smoke screen tanks have four main parts; namely, the tank proper, the tail cone assembly, the exhaust tube, and the carbon dioxide equipment. The Mark 1 smoke tank carrier is an accessory used for lifting, handling, and carrying this tank. Since the obsolescent Mark 6 type tank (30 gallons capacity) is similar to the Mark 5 type, this chapter is also applicable in general to the Mark 6 type tank.

(A) The tank proper has a hoisting eye and two suspension lugs 14 inches apart welded on its upper surface, and a steadying or "bomb" guide key welded on its lower surface. In the nose of the modified Mark 5 Mod 3 tank there is a drainage fitting consisting of a drain plug, an asbestos-neoprene gasket coated with vistanex, and a monel cup. See Ordalt 1499; this Ordalt (applicable to the Mark 5 Mods 2 and 3 smoke screen tanks) changed the gasket material of both the drainage and filling plug gaskets and the four flange gaskets in the tail cone from rubber to an asbestos-neoprene composition coated with vistanex or non-porous TFE polymer. This Ordalt also added a monel cup to the filling and drainage fittings to prevent any washing action on these gaskets. The old rubber gaskets are unsatisfactory for both smoke mixtures and vesicants, since rubber is attacked by smoke mixtures and disintegrates in a few days, and also, rubber is porous to vesicant agents allowing them to pass through the rubber after a day or so. On top of the Mark 5 Mod 2 tank are two filling or drainage fittings similar to the drainage fitting in the nose of the Mark 5 Mod 3 tank.

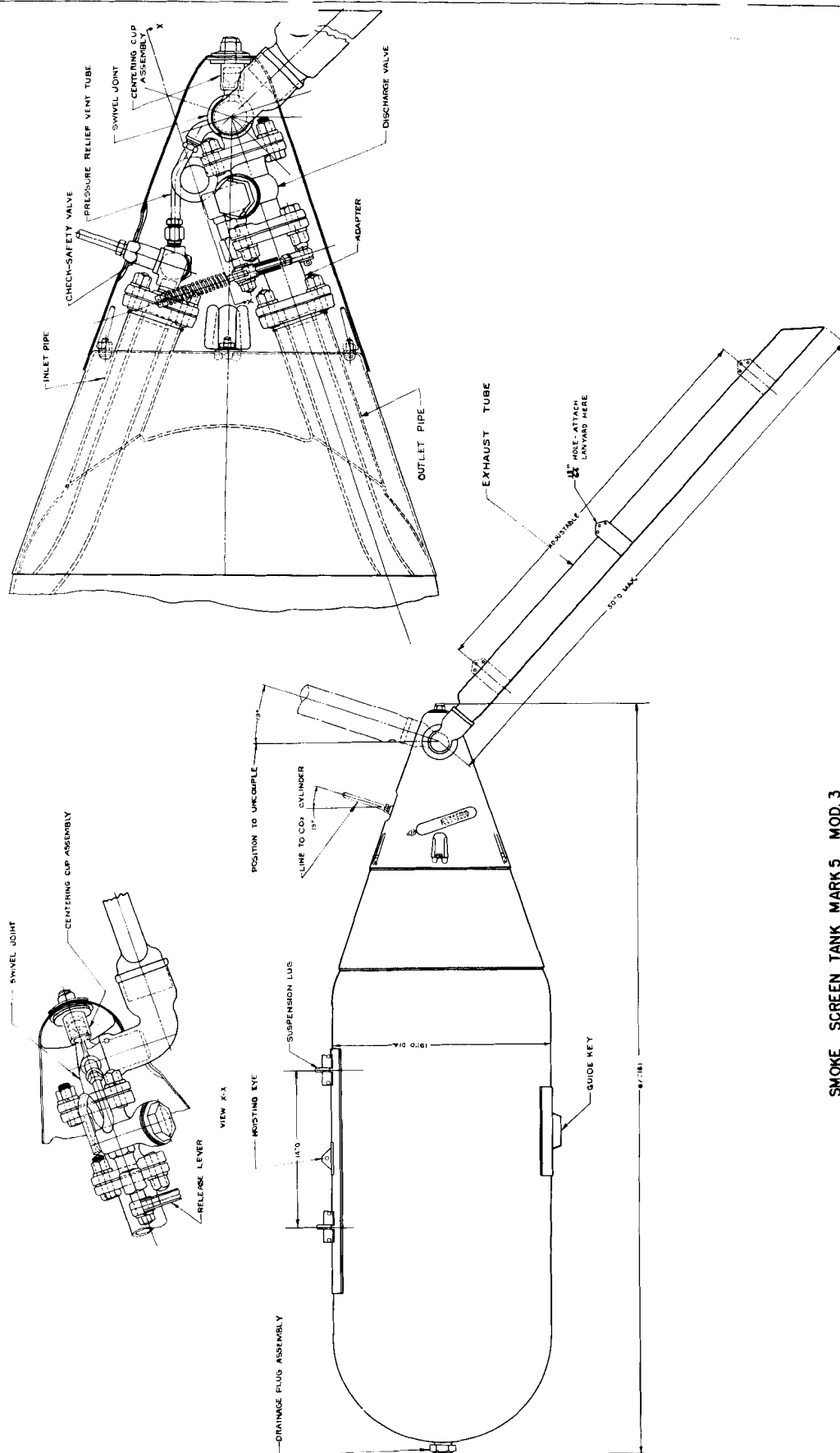
An inlet and outlet pipe extend from the after end of the tanks. Each pipe has a flange welded to it, the flanges being identical. The check-safety valve assembly is bolted to the flange on the inlet pipe, and the discharge valve assembly to the outlet pipe. Three baffle plates inside the tank limit the free surface area of the liquid, thereby preventing sudden shifts of weight.

(B) The tail cone assembly is housed by the tail cone shell which is bolted to the tank proper. At the vertex of the tail cone shell is a centering cup which mates with a post on the swivel body making a ball and socket type connection that insures proper alignment of the various openings in the tail cone shell. Inside the tail cone shell is the check-safety valve assembly, the discharge valve, the swivel body, and the relief tube (see Figure 19).

(1) All the valves in the tail cone assembly depend on contact between ground monel surfaces for sealing. These valves are very dependable when kept in good condition. Each tank, with complete tail cone assembly installed, has previously passed specification tests requiring that they hold 225 pounds per square inch hydraulic pressure without leakage.

(a) The check-safety valve assembly has two spring loaded, plunger type valves, one a check valve and the other a safety relief valve. The check valve is a one-way valve which permits the carbon dioxide to enter the smoke tank but does not permit the chemical agent to back-up into the CO<sub>2</sub> line. The check valve is non-adjustable and opens when the pressure in the carbon dioxide line is approximately 4 pounds per square inch greater than the pressure in the smoke tank. The safety relief valve is adjustable and is usually set to open at approximately 170 pounds per square inch. It is a one-way valve, opening when the pressure in the tank reaches the set pressure, thus permitting the excess CO<sub>2</sub> gas in the tank and any of the chemical agent that may have backed into the valve, to be passed through the relief tube to the swivel body and out the exhaust tube.

(b) The discharge valve is a quick-opening, swinging type, gate valve, which is sealed by contact of the ground surfaces of two disks with two tapered seats. The two disks are separated by the valve stem to which each disk is attached by a ball and socket type joint to provide flexibility for seating arrangement. As the release lever is allowed to lower under its spring tension, the two disks move down between the slightly tapered valve seats to make the seal.



SMOKE SCREEN TANK MARK 5 MOD. 3  
FIGURE 19



(2) The relief tube is a coiled length of 3/8 inch outside diameter monel tubing which has a coupling nut on each end for connecting to the relief valve and swivel body.

(3) The swivel body resembles a pipe elbow with an aligning post projecting aft, a flanged connection for bolting to the discharge valve on one end, and a locking lug and machined outside surface on the other end. The machined surface mates with the machined surface inside the swivel elbow on the exhaust tube; thus making a "bayonet" type joint that locks the exhaust tube to the swivel body. The aligning post protruding from the after end of the swivel body mates with the tail cone centering cup. A threaded opening is provided in the swivel body for attaching the safety relief tube coming from the check-safety valve.

(C) The straight exhaust tube, which is used for wing or external installations, is approximately 50 inches long and has a "bayonet" type fitting on one end that mates with the lug on the swivel body for locking the exhaust tube to the smoke tank. An adjustable clamp is bolted to the exhaust tube for attaching a lanyard that is used to raise or lower the exhaust tube. Installations where the smoke tank is carried in a bomb bay require a Mark 1, 2 or 3 type hinged exhaust tube (see Chapter 5 on hinged exhaust tubes) in place of the straight exhaust tube. When the straight exhaust tube is lowered it falls to the discharge position of its own weight without the assistance of a spring.

(D) The carbon dioxide equipment is located in the fuselage of the airplane, and consists of a carbon dioxide cylinder, a cylinder valve, and a pressure regulator and gauge. The empty cylinder with valve weighs approximately 20 pounds, and is 6-3/4" in diameter, and 19" long. The capacity of this cylinder is 12.6 pounds of CO<sub>2</sub>. The cylinder valve is a quick opening, globe type valve which screws into the top of the CO<sub>2</sub> cylinder; the valve is sealed by metal to metal contact and may be opened by removing the locking pin from the handwheel and turning the handwheel in a counter-clockwise direction. The pressure regulator (with gauge) is screwed directly to the cylinder valve.

(1) The CO<sub>2</sub> cylinders used with smoke tanks are not equipped with syphon tubes, as is the case with CO<sub>2</sub> fire extinguishers, since liquid CO<sub>2</sub> (instead of CO<sub>2</sub> gas) entering the smoke tank would produce a dangerously high pressure unless very carefully controlled. Likewise, the CO<sub>2</sub> cylinder must be installed in the plane with the valve end up so CO<sub>2</sub> will be discharged. The regulators furnished with smoke tanks are designed for regulating the flow of CO<sub>2</sub> gas only.

(2) The regulator valve not only permits control of the smoke tank discharge rate, but also acts as a safety valve since it prevents the building up of dangerous pressures in

the CO<sub>2</sub> line or the tank. The maximum obtainable regulator pressure is about 200 pounds per square inch, either static or flowing. The regulator has two other safety features, a safety outlet plug and the fact that excessive pressure will rupture the rubber diaphragm.

(E) The Mark 1 carrier was previously known as a hoist fitting. It is a device for lifting, handling, and carrying smoke tanks Mark 5 and 6 types. It has a shackle on the after end for handling, and a locking device on the after suspension hook prevents accidental release of the tank from the carrier.

2. Suspending the Tank from the Airplane. The smoke tank may be suspended from an airplane on a two hook bomb rack mounted under the fuselage or wing, or from a two hook rack in the bomb bay. It also may be suspended between two racks or shackles by slings in the same manner as a 1600 or 2000lb. bomb. The smoke tank is secured to the bomb rack (a Mark 35 or 51 type) in the same manner as a double lug bomb. When suspending the tank by slings, the guide key (see Figure 19) may be inserted in the socket provided on some airplanes. This prevents the tank from moving fore and aft. Also, if using the guide key in sling suspension, it is necessary to rotate the tail cone assembly 180 degrees. This is done by removing the tail cone shell and exchanging the position of the check-safety valve and the discharge valve on the tank flanges. Other methods of sling suspension do not make use of the guide key and, in these cases, the tail cone assembly is not rotated 180 degrees. Since the main purpose of the tail cone shell is for streamlining, it may be omitted from bomb bay installations. The flexible tubing (usually contractor installed) connecting the CO<sub>2</sub> regulator valve and the check-safety valve should be made of two sections of flexible tubing joined together by a short rubber tube coupling. When connecting the lanyards that operate the tank discharge valve and the exhaust tube (during landing and take off, the exhaust tube may have to be raised in order to clear the deck), the connections should be made using the shear pins (cotter pins) furnished, or similar shear pins. Then if it becomes necessary to jettison the tank, the shear pins and the rubber coupling on the CO<sub>2</sub> line will permit the tank to fall clear of the airplane. If necessary, the airplane can be maneuvered to produce an additional strain on these breakable connections, that is, zooming will increase the downward force on these connections to assist in breaking them.

3. Operation - The contents of the Mark 5 type Smoke Screen Tank are discharged from the tank by the CO<sub>2</sub> gas. The rate of discharge is controlled by the pressure in the tank, which is regulated by the carbon dioxide regulator valve. The pressure regulator and indicator permit positive control of the pressure in the tank. The regulator (or diaphragm) pressure is set to the desired amount by turning the adjusting screw in or out, which changes the compression in the adjusting screw spring.

U.S. PHOTO. NO. 20562(V). Emission of chemical agent (MR and water) from one  
W.K. 5-2 Smoke Tank on SB2A-4. Altitude - 250 ft. Speed - 250 M.P.H. March 30,  
1943.



FIGURE 20.

(A) The regulator throttle valve (see Figure 21) is balanced in an open position between two main forces, the pressure of CO<sub>2</sub> gas flowing through it from the CO<sub>2</sub> cylinder, tending to close the valve (valve spring also tends to close valve), and the pressure in the adjusting screw spring acting on the valve stem through the diaphragm, tending to open the valve. The throttle valve follows every movement of the diaphragm, quickly restoring any minutely changed diaphragm pressure to its originally set amount by slightly opening or closing. The operating principle of the regulator is that an increase in diaphragm pressure (more CO<sub>2</sub> pressure) moves the diaphragm in a direction away from the valve stem allowing the flow of CO<sub>2</sub> gas to cause the throttle valve to follow this movement and close slightly, which in turn limits the flow of CO<sub>2</sub> and thereby decreases the diaphragm pressure allowing spring pressure to cause the diaphragm to move towards the valve stem, which also moves the valve stem and opens the throttle valve slightly, etc., until the forces are in perfect balance. Actually, the movement of the throttle valve and diaphragm is a smooth process that prevents any appreciable change in diaphragm pressure which would cause the throttle valve to over-compensate for pressure changes as illustrated above. Excessive friction in the moving parts (springs, etc.) would, however, cause a lag in initial movements and thus produce chattering or rapid oscillation of the throttle valve.

#### 4. Operating Procedure

(A) Prior to take off, the regulator valve should be tested. This may be done by turning the regulator valve adjusting screw out (as far as possible in the counter-clockwise direction). Then remove the locking pin that locks the CO<sub>2</sub> cylinder valve and open this valve permitting the CO<sub>2</sub> gas to travel up to the regulator valve. If the regulator valve is seating properly, it will not allow the CO<sub>2</sub> gas to pass through the regulator valve and to the smoke tank, and the pressure indicator will remain on zero. It is important that this valve seat properly because if the valve leaks, an excessive pressure will be built up inside the regulator valve assembly which might pull the edges of the regulator diaphragm out from between the regulator body and the spring housing. If the edges of the rubber diaphragm are thus pulled loose, the CO<sub>2</sub> will enter the airplane cockpit instead of the smoke tank, and necessitate installation of a new diaphragm. After checking the regulator valve, the cylinder valve should be closed and secured with the locking pin.

(B) Just prior to starting a chemical spray run, the exhaust tube should be lowered (if not permanently lowered) by releasing the tension on the exhaust tube operating lanyard. The force of gravity, aided by a coiled spring on Mark 1, 2, or 3 type hinged exhaust tubes (see Chapter 5), will pull the exhaust tube down so that the airplane will not be contaminated. The lanyard should be

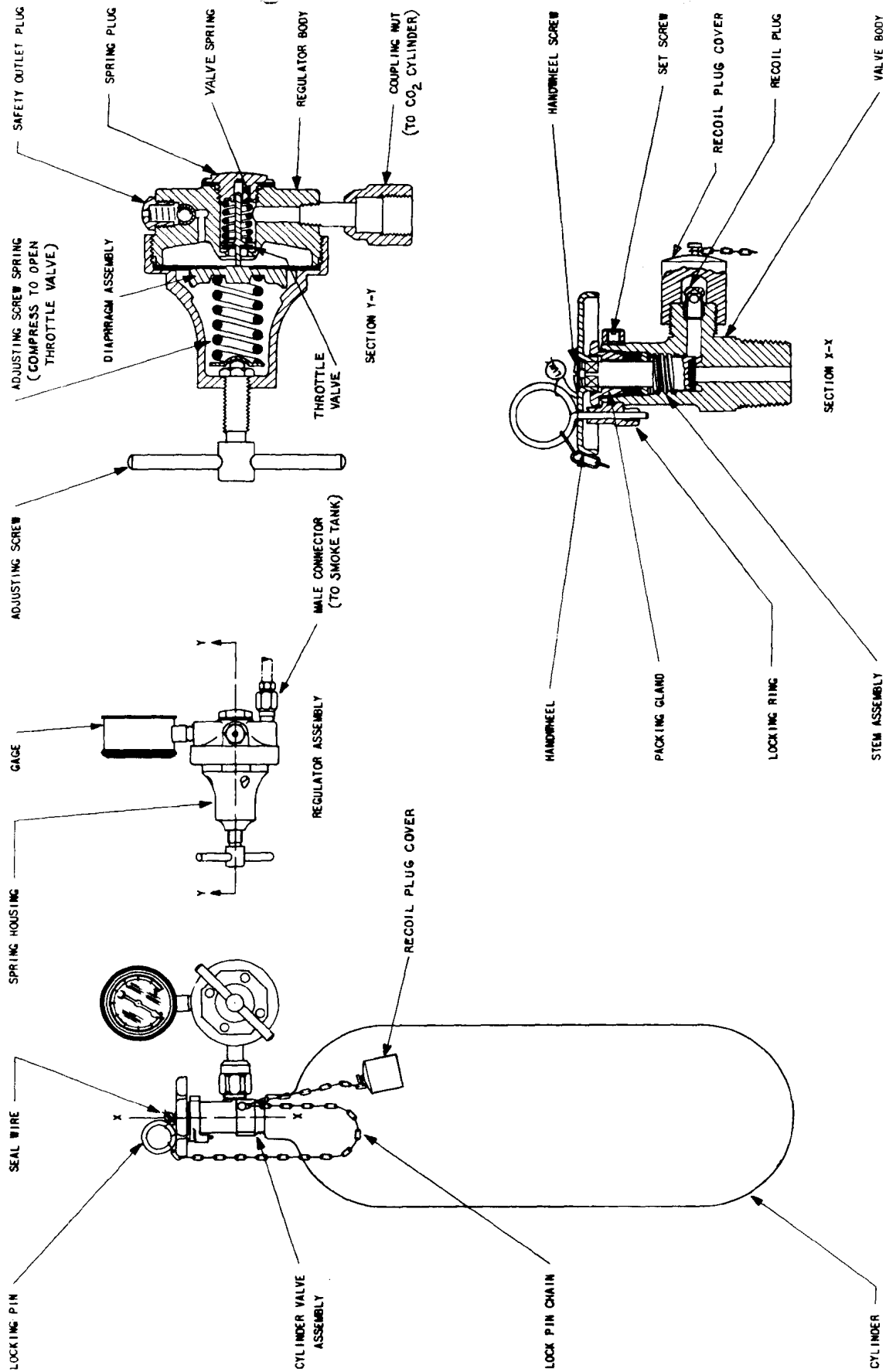
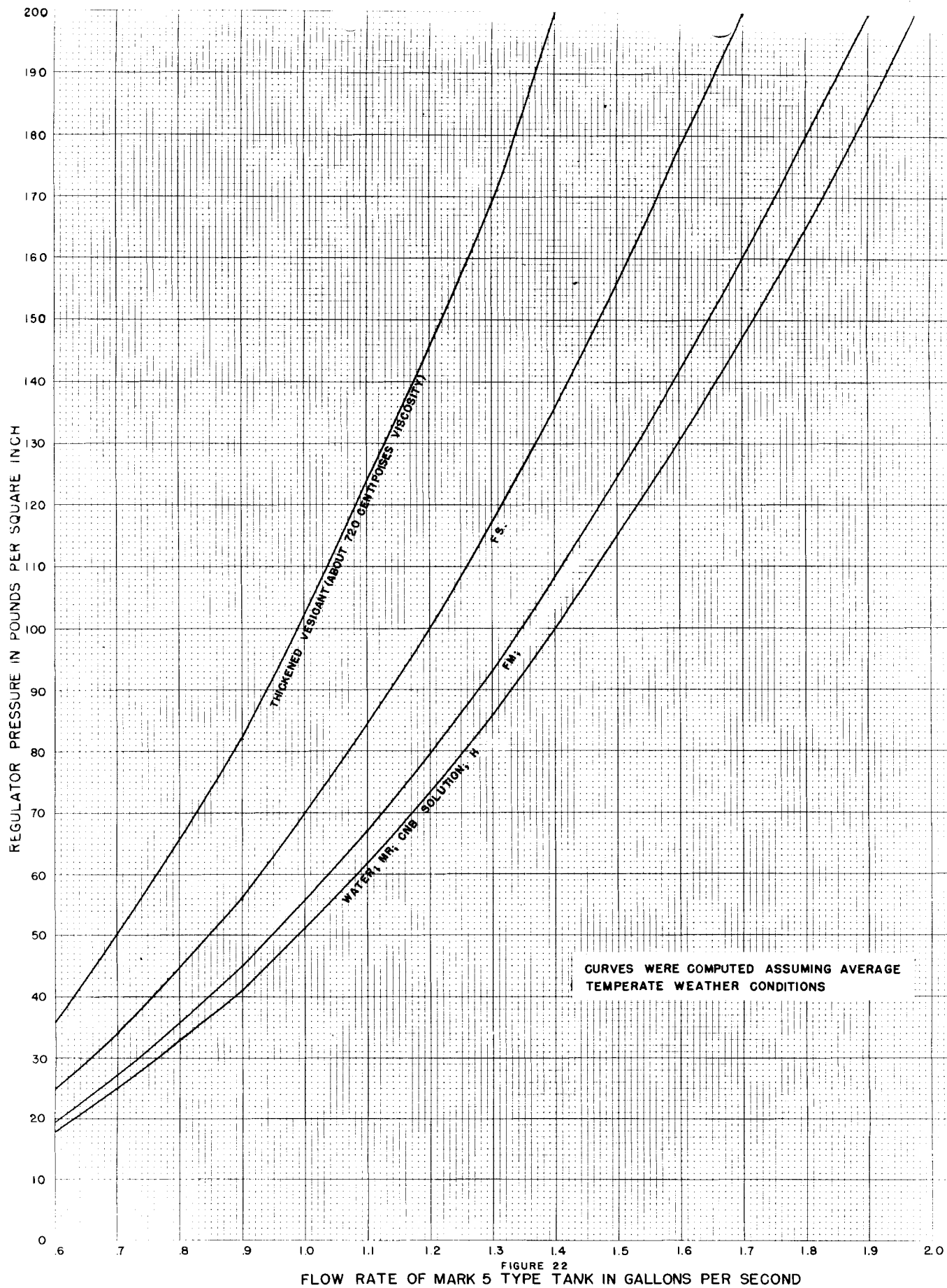


FIG. 21  
SMOKE SCREEN TANKS, MK.5 & MK.6 TYPE  
CO<sub>2</sub> EQUIPMENT — GENERAL ARRANGEMENT

marked or the stop adjusted so the correct position of the exhaust tube can be obtained. The locking pin on the CO<sub>2</sub> cylinder valve should then be removed, the seal wire having been broken prior to take off when testing the regulator valve. The adjusting screw of the pressure regulator should be screwed out, if it is not already in that closed position, then the CO<sub>2</sub> cylinder valve is opened completely. The desired pressure may then be obtained by slowly opening the regulator valve (clockwise direction) until the pressure gauge indicates the desired pressure; however, the regulator pressure should not be increased to a point where it will become as great as the pressure necessary to open the smoke tank safety relief valve (usually 170 pounds per square inch), until a few seconds before opening the tank discharge valve, since CO<sub>2</sub> gas would be unnecessarily lost through an opened relief valve. At no time should the regulator pressure exceed 225 pounds per square inch. Since sudden pressure changes may jerk the edges of the rubber diaphragm out from its permanent seat between the regulator body and the spring housing, it is important that the regulator valve be closed (out-position) when opening the CO<sub>2</sub> cylinder valve.

(C) The contents of the smoke tank are released by firmly pulling the discharge lanyard (opens tank discharge valve); the rate of flow may be adjusted further by turning the adjusting screw in or out, as the case may be, until the desired regulator pressure is obtained (see Figure 22 to estimate the regulator pressure to use). An intermittent discharge may be obtained simply by opening and closing the discharge valve if the liquid level is still above the top of the outlet pipe. When the liquid level in the tank falls below the top of the outlet pipe, the rate of discharge of the chemical agent tapers off, and the indicated regulator pressure falls because CO<sub>2</sub> gas is now being discharged with the chemical agent. Opening and closing the discharge valve several times will facilitate emptying the tank as completely as possible; however, the regulator pressure (as indicated when the discharge valve is closed) should be adjusted and allowed to fall below 100 pounds per square inch before starting this procedure in order to protect the regulator diaphragm from damage, since otherwise large abrupt changes in pressure would occur during the absence of the higher resistance of a purely liquid flow. After emptying the smoke tank, close the CO<sub>2</sub> cylinder valve and allow the regulator pressure to drop to zero before closing the discharge valve. This procedure insures that the tank will be brought back without an internal pressure that would require greater caution in further handling of the tank. After closing the discharge valve and airing the tank by flying about 15 to 30 minutes more, raise the exhaust tube (if necessary) to its retracted position.



5. Stock Numbers. The following stock numbers have been assigned to the equipment described in this chapter:

TANK, Mark 5 Mod 2 (complete except for CO <sub>2</sub> equipment)	3-T-151
TANK, Mark 5 Mod 3 (complete except for CO <sub>2</sub> equipment)	3-T-152
TANK, Mark 6 Mod 2 (complete except for CO <sub>2</sub> equipment)	3-T-156
TANK BODY for Mark 5 Mod 3 Tank	3-T-273
TANK BODY for Mark 6 Mod 2 Tank	3-T-273-50
TAIL CONE ASSEMBLY	
Mark 5 Smoke Screen Tank	3-T-125
Mark 6 Smoke Screen Tank	3-T-126
TUBE, Straight Exhaust for Smoke Screen Tanks - Mark 5 and 6 types.	3-T-1700
CYLINDERS, CARBON DIOXIDE	
Mark 5 and Mods	3-C-2520
Mark 6 and Mods	3-C-2525
VALVE, CARBON DIOXIDE, REGULATOR, SMOKE SCREEN TANK	3-V-120
CARRIER, SMOKE TANK, Mark 1	3-C-780
GASKET, FLANGE, FOR SMOKE SCREEN TANKS Mark 5 and Mark 6 types	3-G-532



1 July 1943

Hinged Exhaust Tubes  
Mark 1 Mod 1, Mark 2, and Mark 3

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3.	Differences	65
4.	Stock Numbers	65

1. Purpose and Use. The Mark 1 Mod 1, the Mark 2, and the Mark 3 hinged exhaust tubes are used with the Mark 5 and Mark 6 type smoke screen tanks when these tanks are suspended in the bomb bay of an airplane. The exhaust tube is used to conduct the contents of the smoke tank out of the bomb bay and into the air (see Figure 23).

(A) The hinged exhaust tubes were designed to permit installation in the bomb bays of the following type aircraft:

Mark 1 Mod 1 - - -SB2A, SB2C, TBF  
Mark 2 - - - - -SB2D, SB3C  
Mark 3 - - - - -SB2A, SB2C, TBF, TBU, TBM

2. Description. The main parts of these monel hinged exhaust tubes are as follows:

(a) An "S" shaped tube (not interchangeable). This tube conducts the chemical agent from the tank in a downward and after direction.

(b) Two swivels (for operation in the vertical plane).

(c) A torsional spring and spring stop.

(d) A long, straight tube that is elliptical in cross section. This tube is usually carried in a horizontal position to facilitate landing and take-off, and is lowered for smoking or spraying.

The "S" shaped tube has a permanently attached swivel elbow on one end that mates with the swivel body in the tail cone of the smoke tank. On the other end of the "S" tube there is a swivel spindle that mates with the swivel body on the straight tube. This connection holds the "S" tube to the straight tube and provides the hinge. The torsional spring is on the swivel body attached to the

N.P.G. PHOTO. NO. 20564(V). Mark 1 hinged exhaust tube connected to MK. 5-2  
Smoke Tank in bomb bay of SB2A-4. March 30, 1943.



FIGURE 23

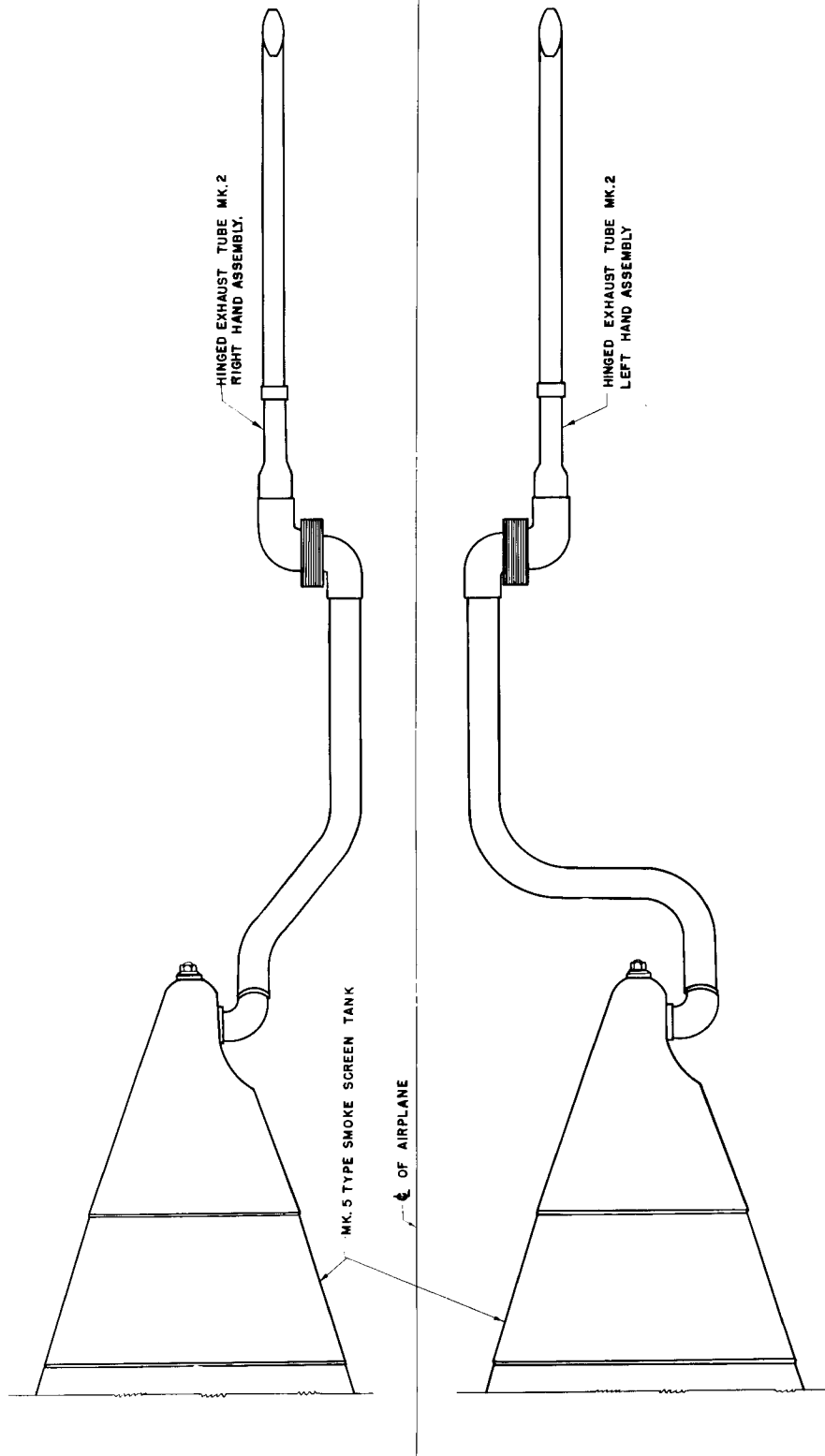


FIG. 24  
 INSTALLATION OF THE MARK 2 HINGED EXHAUST TUBE

straight tube and is hooked to the swivel spindle on the "S" tube. When the exhaust tube is installed on the smoke tank, the spring tends to depress the long straight tube. The straight tube is prevented from being lowered farther than desired by setting the adjustable stop at the position that it is desired to check the downward travel of the straight tube. The stop may be set to the desired position by removing the machine screws that secure it to the swivel spindle and rotating the stop. The straight tube may be maintained in the up position by means of an operating lanyard, which is attached to the clamp on the tube by a shear pin.

3. Differences. The Mark 1 Mod. 1, the Mark 2, and the Mark 3 hinged exhaust tubes are identical except for the "S" tubes which are bent or shaped differently. The "S" tube on the Mark 1 Mod. 1 hinged exhaust tube is approximately 15 inches long and is shaped like an extended "S". The Mark 2 hinged exhaust tubes come in pairs (see Fig.24 ); that is, there are two complete exhaust tubes provided, each with a differently shaped "S" tube permitting right and left hand assembly for installations in which two smoke tanks are suspended in the bomb bay. The "S" tube on the Mark 3 hinged exhaust tube is shaped similar to the "S" tube on the Mark 1 Mod. 1 hinged exhaust tube except that the "S" tube on the Mark 3 is adjustable permitting a 3" variation in the overall length of the "S" tube.

4. Stock Numbers. The following stock numbers have been assigned to the hinged exhaust tubes:

Mark 1 (obsolescent)	3-T-1650
Mark 1 Mod 1 (obsolescent)	3-T-1651
Mark 2 (Pairs)	3-T-1655
* Mark 3	3-T-1656

\* This hinged exhaust tube may replace either the Mark 1 or Mark 1 Mod 1 tubes.

Chapter 6

*1 July 1943*

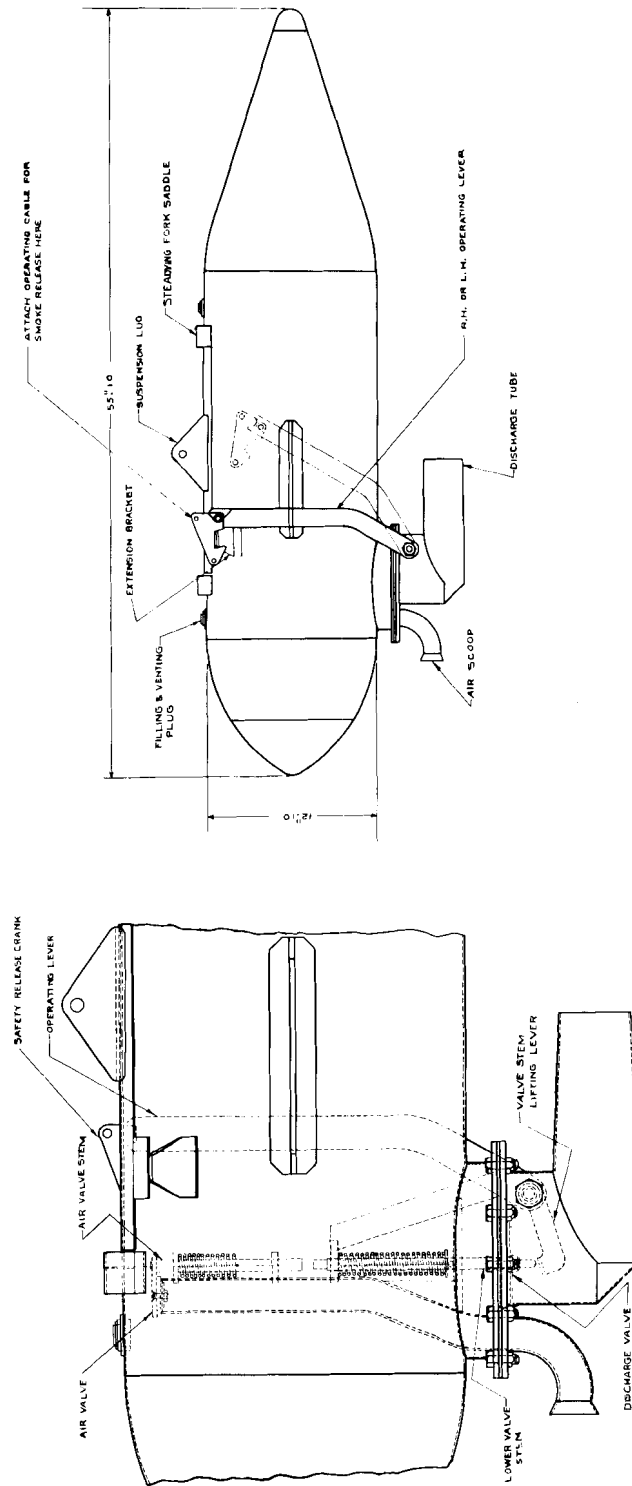
The Mark 7 Mod 2 Smoke Screen Tank

Paragraph		Page
1.	Description	66
2.	Suspending the Tank from the Airplane	68
3.	Operation	68
4.	Operating Procedure	68
5.	Filling Capacity	70
6.	Stock Numbers	70

1. Description. The Mark 7 Mod 2 Smoke Screen Tank is a bomb-shaped monel wing tank used in laying a smoke screen from an airplane. It is approximately 55 inches long, 12 inches in diameter, and has a capacity of 19.1 gallons (no void). The weight of the tank is 45 pounds when empty. The Mark 7 type smoke screen tank with rubber valve disks, is considered obsolete and unsafe for protracted storage; however, this tank can be obtained and used in an emergency (see Paragraph 5 below). The three main parts of the tank are the tank proper, the valve assembly (with air scoop and discharge tube), and the valve operating system.

(A) Tank Proper - Welded topside of the tank proper is a suspension lug, two steadying fork saddles, and the two fittings for the filling plugs which are screwed in almost flush with the surface of the tank. Also welded to the tank are two brackets to either of which the operating lever is locked when in a vertical position. These brackets are just forward of the suspension lug, one being on either side of the tank. Bolted to the flange extending from the underside of the tank is the valve body assembly which includes the airscoop and discharge tube (see Figure 25).

(B) Valve Assembly - Two spring loaded valves, an air valve and a discharge valve, are mounted inside the tank. Both valves are mounted on valve stems which are guided by brackets mounted on the airtube. The valve disks are made of rubber, the valve seats of a nickel copper alloy; the valves will seat satisfactorily if they are properly cleaned after using and are in a good condition. When the valves are closed, approximately 3/8" separates the air valve stem from the discharge valve stem. This gap insures that the valves will seat without binding or interference from each other.



SMOKE SCREEN TANK MK. 7 MOD. 2  
FIGURE 25

(C) Valve Operating System - A right and left hand operating lever is provided with each tank permitting the operating lever to be mounted on either side. The tank has two guide bars welded to it, one on each side, which guide the operating lever as it is pulled aft by the operating cable. A valve stem lifting lever is bolted to the lower end of the operating lever; it rotates with the lever actuating the discharge valve which in turn actuates the air valve.

2. Suspending the Tank from the Airplane. Before the smoke tank is suspended from the airplane, it should be checked to be sure that the tank and its fittings are not leaking and that the operating lever is not binding. The tank is secured to the bomb rack (a Mark 41 or Mark 50 type) in the same manner as single lug bomb. After the smoke tank has been suspended from the bomb rack, attach the operating cable to the operating lever arranging it to give the operating lever a straight pull aft of approximately 6 inches. Care must be taken if using a Mark 50 type bomb rack that the operating cable will not foul on the electrical receptacle. If necessary, the tank may be jettisoned providing that a means of allowing the tank to fall free from the operating cable has been made by incorporating a shear pin.

3. Operation. Since the air scoop on the Mark 7 type smoke screen tank is placed under the tank and in the windstream it scoops up air, piping it into the tank when the air valve is open. The force of this airstream builds up a slight pressure inside the tank facilitating the flow of the liquid from the tank. The force of gravity plus this slight air pressure causes the liquid to be discharged at a rate of about 1.3 gallons per second, the rate of flow being only slightly affected by variations of aircraft speed.

4. Operating Procedure. When it is desired to start spraying the chemical agent, pull the operating cable. The first movement of the operating cable aft, trips the safety release crank unlatching it from the extension bracket; this permits the operating lever to be rotated further aft. The operating lever must be held all the way back during discharge. As the operating lever rotates, the valve stem lifting lever, which is bolted to it at the pivot point, moves upward. As the valve stem lifting lever moves upward, it forces the lower valve stem upward causing the discharge valve to unseat which permits the chemical agent to be discharged. After the lower valve stem moves upward approximately  $3/8$ ", it contacts the air valve stem. Continued movement of the lower valve stem upward, raises the air valve stem unseating the air valve and permits the air scoop to pipe air into the tank. To close the discharge valve, release the tension on the

N.P.G. PHOTO. NO. 20563(V). Emission of Chemical agent (MR and water) from two  
MK. 7 Smoke tanks on SB2A-4. Altitude - 250 ft. Speed - 200 M.P.H. March 31,  
1943.

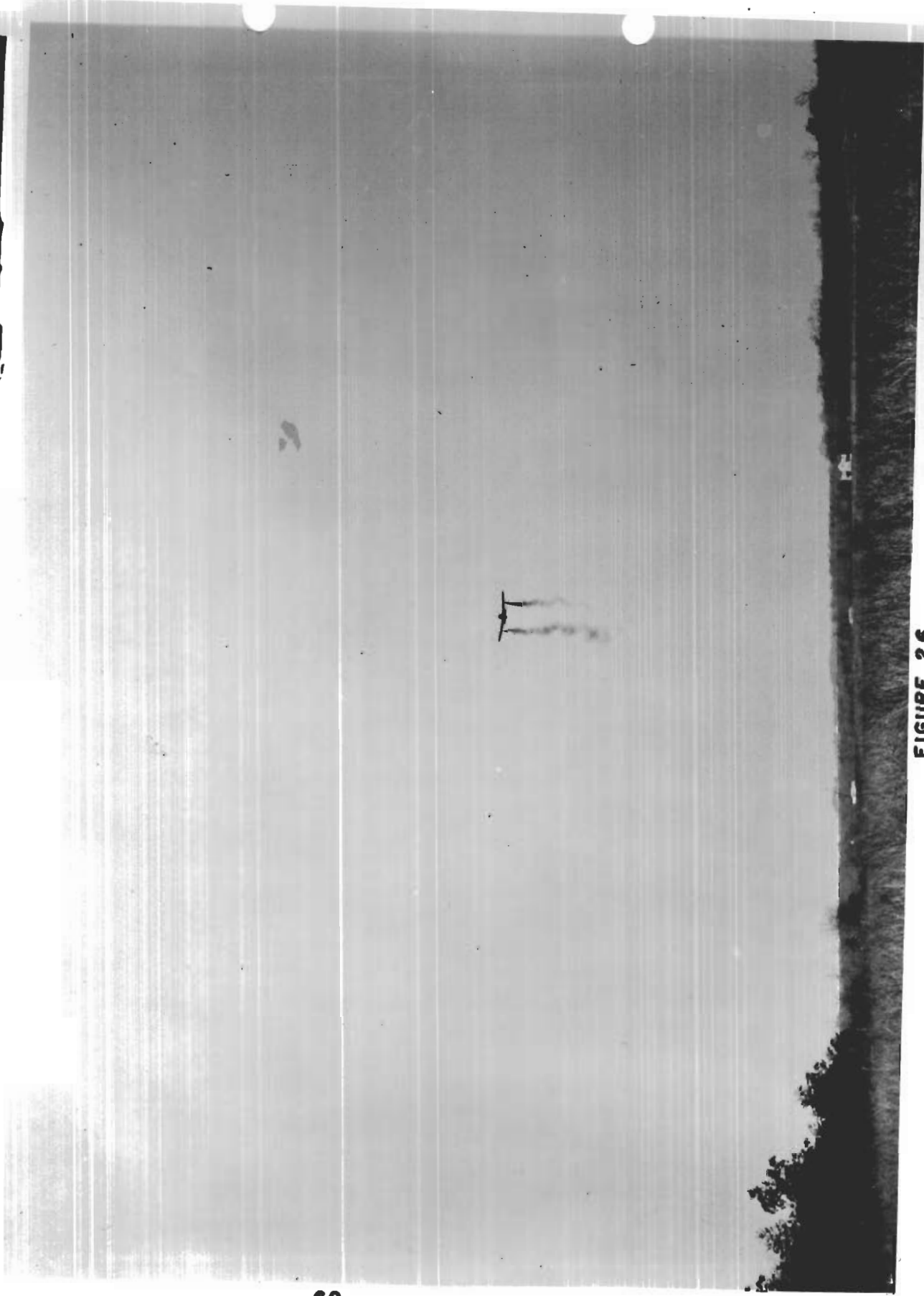


FIGURE 26



operating cable. This permits the valve springs to seat the valves. As the lower valve stem moves downward, it forces the valve stem lifting lever down causing the operating lever to rotate forward to a vertical position. When the operating lever reaches this position, the safety release crank engages the extension bracket securing the operating lever in this position.

#### 5. Filling Capacity.

(A) The Mark 7 type tank (19.1 gallons total capacity) may be filled to 18 gallons (6% void) instead of only 16 gallons (10% void) for the following reasons:

(1) The tank is obsolete mainly because of its limited capacity.

(2) Internal pressure closes the valves tighter.

(3) The standard 10% void is purposely high to allow also for probable maximum errors in the volume of filling in the field; hence, the reduced safety factor can be compensated for by exercising greater care in filling.

(B) This type tank should not be stored for longer than several days when filled with chemical agents, as the present valve disks (rubber) are considered unsafe for long term storage. The rubber valve disks are unsatisfactory for storing either smoke mixtures or vesicants, as rubber is attacked by smoke mixtures and will disintegrate, and also rubber is porous to vesicants allowing penetration after a day or so. However, neoprene valve disks will make the tank satisfactory for long term storage (at least 6 months) of vesicants, but not smoke mixtures. Special care should be taken not to load more than the specified amount (18 gallons) of chemical agent in this tank. The operating lever should not be installed while the tank is in storage in order to prevent accidental release of the chemical agent.

(C) The rubber valve disks have a short life and probably will need frequent replacement. Replacement valve disks should be made of neoprene, as this material is not only impermeable to vesicants, but also more resistant to the highly corrosive smoke mixtures.

6. Stock Numbers. The following stock numbers have been assigned to this tank and several replacement parts.

Tank, Mark 7 Mod 1 Smoke Screen	3-T-160
Tank, Mark 7 Mod 2 Smoke Screen	3-T-162
Discs, Valve for Mark 7 type tank	
Air Inlet (specify "neoprene only")	3-D-647
Discharge (specify "neoprene only")	3-D-648
Gasket, Flange	
For Discharge Tube, Mk. 7 type Tank	3-G-533

Chapter 7

*1 July 1943*

The Mark 1 and Mark 1 Mod 1  
Chemical Filling Equipment

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1.	Description of the Filling Equipment	72
2.	Filling Precautions for Vesicant War Gases	75
3.	Filling Precautions for Smoke Mixtures	76
4.	Filling Procedure	77
5.	Stock Numbers	79

1. Description of the Filling Equipment. The Mark 1 and the Mark 1 Mod 1 Chemical Filling Equipment (monel) consist of a filling hose, a vent hose, a special drainage elbow, and the valves, gaskets, and adapters that are necessary for filling a smoke screen tank with a liquid chemical agent. The Mark 1 Chemical Filling Equipment can be used for filling a Mark 5 or a Mark 6 type (obsolescent) smoke screen tank; the Mark 1 Mod 1 Chemical Filling Equipment can be used to fill a Mark 5, a Mark 6, or a Mark 7 type (obsolete) smoke screen tank. The Mark 1 and the Mark 1 Mod 1 are identical except that two flange adapters are supplied with the Mark 1 Mod 1 Chemical Filling Equipment. These flange adapters are necessary, when filling a Mark 7 type smoke screen tank, for adapting the flanges on the lower end of the filling and vent hoses to the filling and vent openings in the Mark 7 type smoke screen tank. These flange adapters are not used when filling a Mark 5 or Mark 6 type smoke screen tank, as the flanges on the lower ends of the filling and vent hoses are bolted to the flanges of the inlet and outlet pipes extending from the after end of the smoke screen tank. The above fact in view of the obsolete status of the Mark 7 type tank, puts these flange adapters in the obsolete class with the supply held to minimum; hence, the Mark 1 instead of the Mark 1 Mod 1 chemical filling equipment should be ordered (to conserve material) except in particular cases where the Mark 7 type tank is contemplated for use. Using this chemical filling equipment permits transferring the liquid chemical agent from the shipping drums (55 gallon capacity drum) to the smoke screen tank with a minimum exposure of the liquid to the atmosphere. The liquid entering the smoke screen tank displaces the entrapped air and vapors; these vapors are then vented back into the shipping drum, thus giving a closed filling system.

(A) The filling and vent hoses are respectively one inch and three eighths of an inch in diameter. All the fittings,

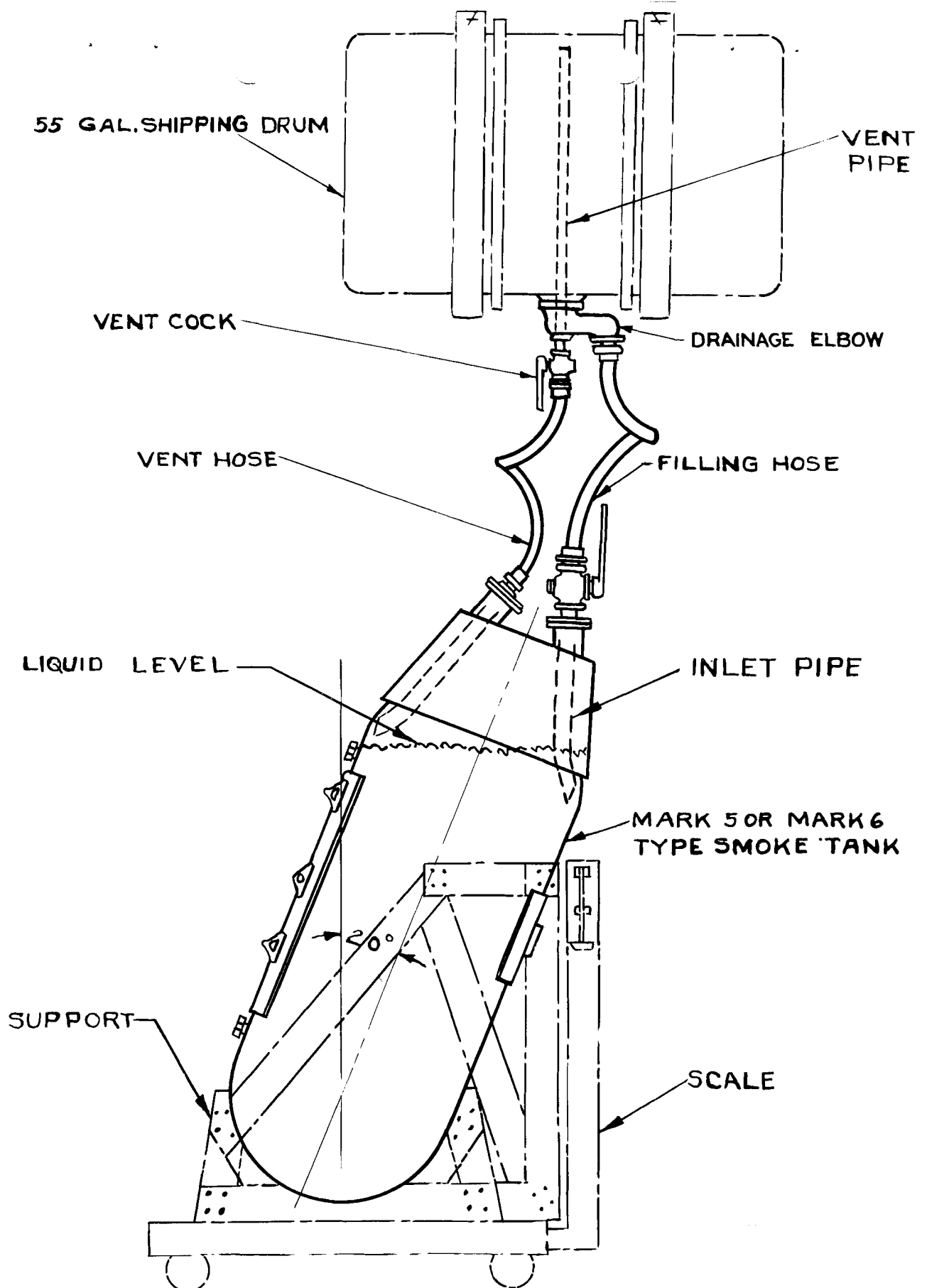


FIGURE 27  
FILLING A MARK 5 TYPE SMOKE SCREEN TANK  
-73-

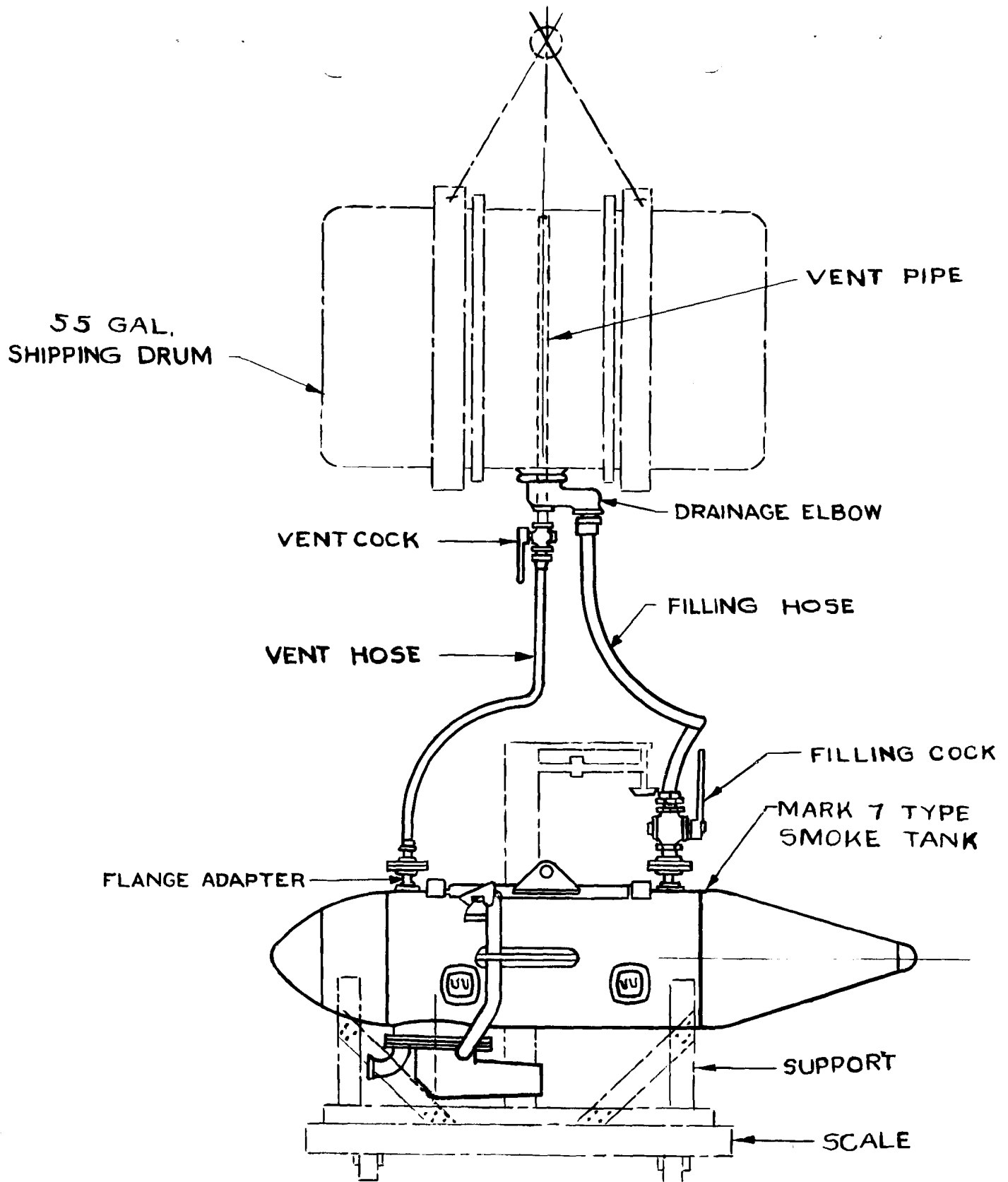


FIGURE 28

FILLING A MARK 7 TYPE SMOKE SCREEN TANK

nipples, and flanges necessary to connect these flexible metal hoses to the smoke screen tank, as well as a straightway cock type valve for each hose, are provided with this equipment.

(B) In addition to the Chemical Filling Equipment, it is necessary to use a scale capable of weighing up to 1000 pounds or more, a supporting stand for holding the smoke tank on the scale in the filling position, and a hoist with the necessary accessories for raising the shipping drum above the smoke screen tank (see Figures 27 and 28).

## 2. Filling Precautions for Vesicant War Gases.

(A) A competent officer should be in charge of filling operations at all times, and all personnel in the filling detail should have had previous training in this work.

(B) Filling operations (except for smoke mixtures) should not be attempted aboard ship, except under expert supervision, as vesicant war gases are too dangerous to risk exposing the complement of a ship to the added hazards that are likely to accompany such filling operations. At present most of the filling will be done at regular filling depots or at field stations set up for this purpose.

(C) All war gases are dangerous, and great care must be taken when handling them. Those engaged in filling operations, and those in the immediate vicinity, should be provided protective clothing and gas masks, and there should be on hand a sufficient amount of the proper decontaminating agents, first aid materials (see Chapters 8 and 10), and the necessary tools.

(D) Filling operations should be conducted downwind from personnel and equipment so that toxic fumes will not be blown towards them.

(E) Any chemical agent that has been spilled on the equipment or ground should be immediately decontaminated using the proper decontaminating agent(s) (see Chapter 8). Waste contaminated with a chemical agent should be removed as used and burned, or otherwise properly disposed of, and all tools contaminated or likely to have been contaminated should be wiped off with the proper decontaminating agent absorbed in an adequate amount of waste.

(F) Extreme caution must be exercised in the handling and dismantling of the filling line after use, in order to prevent contamination of personnel or equipment from drops of the chemical agent which may drip or be splashed. A metal, trowel-like instru-

ment that can be decontaminated easily may be used to catch any drippings.

(G) Before preparing an unused tank for filling, it should be carefully inspected to be sure that it is clean and dry (water in vesicants forms corrosive acid, generates gas pressure), and that no cracks have developed due to rough handling. Any worn or broken parts should be replaced, especially defective gaskets. A suitable grease such as a soft graphite grease is recommended for use on gaskets and threads of equipment only when used with vesicants.

(H) Chemical spray tanks which are to be stored before use should be filled to only 90% capacity since it is advisable to set aside approximately 10% (but not more than 10%) for expansion. (A 6% void is sufficient for the Mark 7 type tank. See Chapter 6, paragraph 5.)

(I) Liquid chemical agents are usually supplied in 55 gallon steel or iron drums equipped with two plugs one in the end and one midway on the side. Great caution should be exercised in removing a plug, since actual experience has shown that an unexpected amount of pressure sometimes develops within the drum. To remove the side plug for installing the filling line, place the drum on its side with the plug at the top. With all personnel standing upwind from the drum, the plug should be removed with a suitable wrench having about a 5-foot length of appropriate-sized pipe slipped over the handle to enable its being worked from a safe distance. An ample amount of waste should be placed around the plug and jaws of the wrench to absorb any liquid which may spatter into the air.

### 3. Filling Precautions for Smoke Mixtures.

(A) Since both FS and FM smoke mixtures act like heavy acids (FS being extremely corrosive when in the liquid state), it is necessary that personnel engaged in filling tanks with a smoke mixture be familiar with decontamination procedure and the safety precautions to be observed when handling these materials (see Chapter 10). Except for the toxicity aspect, the filling precautions for war gases also apply in general to smoke mixtures.

(B) Both FS and FM react with explosive violence when they come in contact with water or grease. Therefore, special precautions should be taken to prevent their coming in contact with these materials, especially when using a closed system of filling. Containers or filling equipment which are to be used with FS or FM should always be thoroughly inspected to be

sure that they are clean, free from grease or foreign materials, and are thoroughly dry. If grease has been applied to the gaskets or threads of any of the equipment, the greased surfaces may be cleaned sufficiently by wiping them with a piece of waste; the small amount of grease remaining will be negligible.

(C) When handling FS and FM, each member of the crew should protect himself from serious injury by wearing acid proof aprons or clothing and neoprene gloves. Since the fumes of FS and FM are not toxic, gas masks are not essential but may be worn if desired.

4. Filling Procedure. The following procedure is recommended when filling smoke tanks.

(A) Place the shipping drum on suitable rails with the side bung of the drum up. Place the smoke tank in a supporting stand and on a scale near the drum. Mark 5 and Mark 6 type smoke tanks should be tilted approximately 20° from the vertical as shown in Figure 27, vent line up. This permits the smoke tank inlet pipe to vent the tank throughout the filling.

(B) A soft graphite grease is recommended for use on the gaskets and threads of all equipment when used with vesicants, but no grease should be used when the equipment is used with FS or FM smoke mixtures.

(C) Remove the screw cap from the bung in the side of the shipping drum and install the drainage elbow being sure that the vent and filling valves are closed and as an added precaution the ends of the hoses may be temporarily plugged with waste.

(D) Roll the drum until the bung end is down between the rails and hoist the shipping drum above the smoke tank. Remove any waste and connect the filling and vent hoses to the smoke tank; be sure that all connections of the filling equipment are tight. At no time should a strain be placed on the filling or vent hoses. After the shipping drum has been hoisted and the smoke tank moved into a position under the drum, there should be enough slack in the filling and vent lines to permit fairly accurate weighing of the smoke tank and supporting stand.

(E) Weigh and record the weight of the empty smoke tank, stand, and filling connections. To this weight, add the weight of the chemical agent that is to be placed in the smoke tank.



NOTE: The number of gallons of charge is important. The weight per gallon varies due to the different densities of the chemical agents. Therefore, determine the weight of one gallon of the chemical agent to be used, and adjust the weight on the scale to suit. (The approximate weight of FS and FM smoke mixture is 15.8 and 14.5 pounds per gallon, respectively; the approximate weight of H and L is 11.2 and 15.6 pounds per gallon, respectively.)

(F) Open the vent valve, then the filling valve permitting the chemical agent to run into the smoke tank. When the scale indicates the weight desired, close the filling valve immediately. Allow the smoke tank to vent for a few seconds then close the vent valve. Failure to follow the above procedure may result in some of the liquid chemical agents being trapped between the filling valve and the smoke tank. This might result in spilling this liquid when removing the filling line from the smoke tank.

(G) After closing the vent valve, cautiously break the joint between the filling hose and the smoke tank, allowing any liquid which might be entrapped to drain into the tank. Disconnect the filling lines from the loaded smoke tank, using an ample amount of waste or a metal trowel to catch any liquid which may drip. Waste may be used to keep all openings temporarily closed.

(H) For the Mark 7 type smoke tank, remove the waste and screw in the vent and filling plugs. For the Mark 5 type tank, remove the waste and carefully install the blank flanges or the tail cone assembly. If installing the complete tail cone assembly for storage, fold in the end of the discharge valve operating lever, and cover the opening for the lever in the tail cone with a sufficient amount of masking tape or some other suitable material. Put a small piece of tape over the check valve port, and plug the swivel body discharge opening with a piece of waste. Secure the lanyard fitting (with shear pin) for the operating lever to a convenient part of the tail cone assembly, for future use. When installing the tail cone assembly for storage, the inlet pipe should be located in the usual position on the same side as the suspension lugs. The tail cone assembly can be rotated later if necessary for a particular installation, since this case probably will not be encountered.

(I) After filling the last tank, lower the shipping drum, replace the screw cap, and clean all filling equipment (see Chapter 8).

(j) After the smoke screen tanks have been filled with a chemical agent they should be inspected for possible leaks (see Chapter 9). A tank which shows evidence of leaking should have its contents transferred immediately to either another tank or back to a shipping drum. The defective tank should then be thoroughly decontaminated and inspected to determine the cause of the leak and the possibility of making repairs.

(k) A suitable tag should be attached to a convenient place on all loaded tanks, the tag to contain pertinent details such as the name of the chemical agent, date, temperature, and place of filling, the weight of the contents, and the estimated maximum storage period before a stability inspection should be made at a filling depot.

5. Stock Numbers. The following stock numbers have been assigned to the filling equipment:

Filling Equipment, Chemical Mark 1	3-F-110
Filling Equipment, Chemical Mark 1 Mod 1	3-F-112

1 July 1943

Decontamination, Care and Maintenance of Equipment

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2.	Care and Maintenance of CO <sub>2</sub> Equipment	83
3.	Decontamination after a Spraying Mission	84
4.	Decontaminating Agents for a Smoke Mixture	88
5.	Decontaminating Agents for Vesicants	89

1. Care and Maintenance of Tanks---Empty tanks should never be stored unless exposed contaminated surfaces have been cleaned and decontaminated. Tanks which are to be stored empty for a considerable length of time, should be completely disassembled, cleaned thoroughly, and inspected for leaks and wear, especially the valves and gaskets, and then reassembled. No lubrication is necessary for monel tanks and parts. Tanks should be stored, if possible, in a dry place and in a place where they will not become dented, punctured, or damaged in any way. Before use, each tank should be carefully inspected to be sure that all parts of the tank will operate properly. Due to the corrosive action of smoke mixtures and the harmful effects of vesicants on personnel and equipment, the possibility of leaks in the tank proper, valves, any flanged connections, and the inlet and exhaust line connections should be investigated before filling any tank with a chemical agent.

(A) The tank proper may be checked at the same time the tank is being cleaned prior to filling with a chemical agent, by filling the tank with water. After filling with water, any water which may have been spilled on the exterior of the tank should be wiped off and the tank then inspected for leakage. Special attention should be given to manipulating the tank so that the drainage plugs, filling and vent plugs, valves, and flanged connections are each placed in the lowest relative position for checking these seals.

(B) Special attention should be given the discharge valve when checking it to be sure that it may be opened readily without any tendency to stick.

(1) On the Mark 7 type smoke screen tank there are two valves to be checked, the discharge valve and the air inlet valve. Both valve discs should be checked to be sure that they are in good condition and that the valve springs have sufficient strength (designed for 50 lbs. pressure) to keep the valves in a tightly closed position.

or 6  
(2) On the Mark 5/type smoke screen tank there are two valve assemblies to be checked, the discharge valve and the check-safety valve.

(a) A leaking discharge valve can usually be discovered when the tank proper is filled with water in order to check it for leakage. A leaking discharge valve permits a steady, continuous dripping of water from the exhaust line. Leakage results from the separation of the ground surfaces of the valve discs and valve seats, and is usually due to the presence of foreign solid particles between these surfaces. Particles may lodge on the disks or seats, or in the recess in the valve body between and below the seats. If leakage occurs, the tank should be stood on end, nose down, and the valve opened and closed rapidly several times by working the release lever. If this does not stop the leakage, the valve should be removed and inspected at the first opportunity. Material accumulated in the valve body recess may be removed by thoroughly flushing with water or air from an air pressure line. When leakage is due to damage or wear of the ground surfaces of the disks or seats, the valve should be replaced. The discharge valve should be inspected frequently for leaks around the valve stem; such leakage is corrected by drawing up the packing nut just tight enough to stop the leak.

(b) The relief valve, in the check-safety valve assembly, ordinarily is adjusted to blow off when the pressure reaches 170 pounds per square inch. To adjust this valve (relief valve) the inlet flange of this valve is connected to the discharge valve, and the check valve port to some source of air or CO<sub>2</sub> pressure with the regulator and pressure gauge between the valve and source of pressure. A flange gasket should be used in the connection between the check-safety valve and the discharge valve. The relief valve adjusting screw cover is removed and the screw locknut loosened; then the pressure is increased carefully until it rises sufficiently to open the relief valve. The adjusting screw of the relief valve should then be screwed in or out until the indicated pressure can be increased to 170 pounds per square inch before the relief valve opens. After setting the safety relief valve to open at 170 pounds per square inch, the screw locknut should be tightened, being careful that the adjusting screw does not turn during this operation, and the adjusting

screw cover replaced. (Before disconnecting the pressure supply, all the valves can be checked carefully for leaks). To check the safety relief valve for either a defective spring or improper seating of the valve, it is necessary to disassemble the valve, which is easily accomplished as follows:

- (1) Remove the adjusting screw cover.
- (2) Remove the adjusting screw lock nut and the adjusting screw; this relieves the tension in the safety relief valve spring.
- (3) Remove the body cover.
- (4) Remove the safety valve (plunger).

Reassembly of the relief valve is accomplished by reversing the above procedure. After reassembly the valve should be adjusted as already described. The complete check-safety valve assembly and the discharge valve should be inspected for leaks and sticking whenever the tank has been filled and discharged approximately six times, or on disassembling the tank for storage, and at any sign of malfunctioning. To check for leaks in the check-safety valve assembly and the discharge valve, the CO<sub>2</sub> tube end of the check valve should be connected, as previously described, to a pressure source (CO<sub>2</sub> or air) with the discharge valve bolted to the assembly using a good flange gasket in the connection. After loading the assembly with 50 to 100 pounds pressure, the pressure line should be removed and all valve ports covered with a film of soapy water and watched for bubbles. The duration of this test should be about five minutes. At the conclusion of the test, a rush of air should be heard when the discharge valve is opened. If a valve

leaks, it should be removed and the cause of leakage corrected. The check valve is disassembled by removing the set screw and unscrewing the check valve body. The most probable causes of leakage are:

- (1) Presence of foreign particles on the ground valve surfaces which prevents the valve disk from seating properly.
- (2) Pitting of the ground surfaces which allows passage of gas or liquid between the disk and seat.

If no pitting has occurred, the ground surfaces of both seat and disk should be wiped clean and replaced, using extreme care that no particles of dirt become lodged on the seat or disk. When either seat or disk is pitted, nicked, or otherwise damaged, the valve should be replaced. Any new fittings or tubing attached to any of the valves should be cleaned thoroughly removing all dirt, water, and metal filings or shavings. Since cold (expanding) CO<sub>2</sub> gas will rapidly freeze any water present in the CO<sub>2</sub> line or valves, care should be taken that the line and valves are thoroughly dry when installed.

2. Care and Maintenance of CO<sub>2</sub> Equipment-- Filled CO<sub>2</sub> cylinders will ordinarily be supplied to the service units. Should it be necessary to recharge cylinders in the field, the following procedure may be followed. The large cylinder of CO<sub>2</sub> from which the charge is to be taken is laid on its side with the valve in the lowermost position. Then a flexible piece of metal tubing which has the proper fittings is used to connect this cylinder to the smaller CO<sub>2</sub> cylinder. The smaller CO<sub>2</sub> cylinder should then be placed upon a small platform scale so that the proper weight of filling can be measured and the cylinder filled to this proper weight. The CO<sub>2</sub> cylinder has marked on it the net weight of the cylinder and the proper weight of the cylinder when filled. The regulator should not be shipped attached to the filled CO<sub>2</sub> cylinder, and it should not be permitted to remain attached to the cylinder for any appreciable time when not in use. Cylinders that are to be recharged in the field should be filled to the proper weight immediately after the airplane returns from its mission; the cylinder will take a charge easier if it is recharged while it is cold.

(A) If any part of the CO<sub>2</sub> tube between the regulator valve and the tank has become contaminated, it should be washed with an abundance of water or with the proper decontaminating agent and then with fresh water, blown dry with air, and allowed to hang in a dry place until required for another mission. Since

any moisture present in the CO<sub>2</sub> line will probably freeze as the CO<sub>2</sub> gas is discharged, this line must be kept thoroughly dry.

(B) Periodically the regulator valve should be disassembled and all parts thoroughly cleaned, dried, and inspected. No lubrication of the regulator valve is necessary with the possible exception of dipping the lower end of the valve spring in glycerine which minimizes any tendency of the valve to chatter. When the regulator is not in use the adjusting screw should be turned out as far as possible (in the counter-clockwise direction) in order to relieve the pressure on the adjusting screw spring and prevent it from taking a permanent set. A weakened spring will decrease the maximum regulating pressure that can be obtained.

### 3. Decontamination after a Spraying Mission

(A) Immediately upon completion of a spraying mission, the spray tank(s) should be removed from the airplane and the airplane and landing area inspected for contamination. Under normal circumstances neither the airplane nor the landing area will be contaminated. Usually new installations are thoroughly tested in flight by using spray tanks filled with a molasses residuum solution (MR), a harmless, dark brown liquid that is easily discernible on almost any surface. However, if there is any evidence of contamination of the airplane after spraying a vesicant, the airplane should be immediately segregated downwind from personnel until decontaminated. After the chemical agent has been discharged from spray tanks, further flying for 15 to 30 minutes usually eliminates all dripping and prevents any contamination of the flight deck or runway. It is practical for slightly dripping spray tanks to be brought back with the airplane, since the few resulting contaminated spots are easily rendered harmless by the proper decontaminating agent and, being in the open, the vapor danger is negligible. Porous substances like concrete and wood are very difficult to decontaminate completely if the vesicant has had time to penetrate deeply, but even in this case the small spots can be marked and direct contact with them avoided until in time rendered completely harmless to touch. Consideration might be given to wetting down the landing area or to the use of disposable absorbents or strips of impermeable materials on areas likely to become contaminated when the airplanes are landing. Every reasonable effort should be made to conserve all spray tanks, especially those constructed of monel (critical metal).

(B) Aboard ship it may be more practical to seal all openings in the spray tanks and decontaminate any contaminated exposed surfaces only, such as those portions of the inlet and exhaust

assemblies outside the sealed sections, leaving the more difficult decontamination to be done at the filling depots ashore.

(1) For the Mark 5 type tank the swivel body port (the only part not sealed by valves or caps) should be plugged with a neoprene stopper or by some other suitable means; this eliminates the difficult job of decontaminating the tail cone section beyond the discharge valve. Rather than attempting to seal the end openings in the exhaust tube, it will probably be simpler to decontaminate the whole tube.

(2) For the Mark 7 type tank, any contaminated outside surfaces, the air scoop, and discharge tube should be thoroughly decontaminated, keeping the valves closed all the time.

(3) Army M-10 (or M-33) spray tanks usually are recommended to be jettisoned after a vesicant spraying mission. These tanks are considered somewhat expendable since they are constructed of light gage copper-bearing or mild steel; however, if these tanks are brought back, the following procedure is recommended. Install the air inlet closure plug and the exhaust closure plate, and then decontaminate the unsealed or exposed portions of the inlet and exhaust assemblies.

(C) All decontamination materials can be put in one or more of the following classes:

(1) Chlorinators and oxidizing agents-- Bleaching powder is the outstanding example of this group.

(2) Hydrolyzing agents--Water is the only hydrolyzing agent.

(3) Neutralizing agents--Alkalis such as caustic soda (lye) or alkaline soaps increase the speed of hydrolysis by the neutralization of the hydrochloric acid which is usually present.

(4) Absorbents and solvents--Solvents do not destroy chemical agents, but simply dilute them. If an area is repeatedly scrubbed it will be freed of most contamination if the swabs are changed frequently. Solvents and soapy water are especially useful in decontaminating airplane surfaces where corrosive chlorinators or neutralizing agents might damage the airplane. Occasionally



small areas of terrain are decontaminated by bleaching powder with an absorbent such as dry earth, sand, ashes, or sawdust in the proportion by weight of one part of bleach to three parts of earth or substitute. This ratio corresponds to two parts of bleach to three parts of earth by volume.

(5) Incinerating materials--These include liquids which can be applied to contaminated surfaces and subsequently ignited, the heat of burning driving off or breaking up any injurious chemical agents. Many materials, such as contaminated waste can be burned without the aid of inflammable liquids, vesicant vapors being somewhat inflammable themselves.

(D) In decontaminating spray tanks, airplane surfaces, etc., the general procedure is the same regardless of the applicable decontaminating agent used. The first step is to rinse, or if possible, to scrub the contaminated object thoroughly with the proper decontaminating material, then rinse with water (salt or fresh) to remove any corrosive decontaminating agents. Volatile solvents may be used after rinsing with water in order to decrease the drying time of the tanks or surfaces. When using highly inflammable solvents such as acetone, alcohol, gasoline, etc., great care should be taken to prevent a serious accident during the drying process; sparks, flame, or any other possible source of fire must be kept away from the vapors. All decontaminating work, drying of tanks, etc. should be done in the open if possible, since closed spaces add to the danger. All waste materials, decontaminating agent, solvent, or water used in the cleaning process should be carefully disposed of since they become contaminated and are themselves a source of danger, especially the initial waste material. Although some decontaminating agents are universally applicable, the effectiveness may vary considerably between different vesicants. For this reason the following decontaminating and rinsing agents are listed in the order of their effectiveness and practicability for the principle chemical agents, including smoke mixtures.

(1) H, HL, and Mixtures of H and HN-2

(a) RH-195 solution, then (e) or (f).

(b) Bleach slurry, (bleach-water mixture) then (e) or (f).

(c) **Caustic** soda (lye) solution, then (e) or (f).

(d) Strong soap (laundry soap) and hot water, then (e) or (f).

(e) Hot fresh water.

(f) Salt water, then (e) if practicable.

(2) L and/or the Nitrogen Mustards

(a) Caustic soda (lye) solution, then (d) or (e).

(b) Strong soap (laundry soap) and hot water, then (d) or (e).

(c) RH-195 solution or bleach slurry, then (d) or (e).

(d) Hot fresh water.

(e) Salt water, then (d) if practicable.

(3) Smoke Mixtures (FS or FM)

(a) Washing soda solution, then (d) or (e).

(b) Sodium bicarbonate solution, then (d) or (e).

(c) Strong soap (laundry soap) and water. then (d) or (e).

(d) Fresh water.

(e) Salt water, then (d), if practicable.

(E) Initial cleaning of the Mark 5 type tank should be done with the exhaust tube attached to the tank. After rinsing the tank out thoroughly, open and close the discharge valve alternately, allowing the rinse to drain out through the exhaust tube. The exhaust tube is then removed from the tank by swiveling it upward until it is approximately perpendicular to the surface of the tail cone. In this position the exhaust tube is unlocked from the swivel joint and may be easily removed. Care must be taken in removing the exhaust tube, especially after toxic chemicals have been used, in order to hold to a minimum the amount of contamination. The exhaust tube and the exposed portion of the swivel body should be decontaminated as soon as practicable. After removing the exhaust tube, the tail cone shell should be removed. This is accomplished by pushing in the discharge valve operating lever, unscrewing the six nuts at the tail cone and pulling the tail cone to the rear. After removing the tail cone shell, add the proper decontaminating agent or solvent to the smoke tank and manipulate the tank in order to wash every part of the interior of the tank. The discharge valve should then be opened and closed alternately permitting the decontaminating agent or solvent to drain from the tank. To clean the discharge valve more thoroughly, the discharge valve cap may be removed and the

valve opened and closed as the cleaning progresses. All surfaces of the tank, both exterior and interior, should be thoroughly decontaminated.

(F) After spray tanks have been thoroughly washed and decontaminated, they should be rinsed with water and then permitted to dry in the sun or in a warm place with all valves and fittings open. Tanks should be so placed that any entrapped liquid will drain. If there is insufficient time for them to dry thoroughly in this manner, the drying time can be materially shortened by flushing them with either acetone or denatured alcohol. First, all water that can be drained must be removed. Then about one gallon of acetone or denatured alcohol poured into the tank and the tank manipulated so that the liquid will come in contact with all the interior surfaces. After rinsing with the alcohol or acetone, the tank should be drained and air blown through the tank until no odor of the drying agent can be detected. A given amount of acetone or alcohol can be used to rinse several tanks in succession. If a supply of compressed air is not available, allow the tanks to stand, with the drainage plugs and inlet and exhaust pipes open, until they are clear of all vapors. After the tanks are thoroughly dry, they should be assembled and stowed in a proper place until further use.

(G) Personnel engaged in decontamination work should wear protective clothing and gas masks. After working around vesicants, it is always a good idea to take a hot bath using a strong soap. It should be remembered that the protective clothing and gas masks may have been contaminated; special care should be taken in removing these clothes. Before leaving the working area, shoes should be dusted with RH-195 or bleaching powder to prevent spreading contamination to other areas.

#### 4. Decontaminating Agents for Smoke Mixtures

(A) Washing soda, sodium carbonate, is also known as soda ash, sal soda, and laundry soda. It is a white, powdery substance possessing mild alkaline properties. Commercial grades may contain large amounts of sodium bicarbonate. To prepare a solution, keep adding washing soda to water while stirring until no more washing soda will go into solution. Washing soda has no serious action upon the skin, eyes, or clothing. Its dust should not be breathed as it is somewhat caustic.

(B) A sodium bicarbonate solution can be prepared in the same manner as the washing soda solution. Either a concentrated

solution or a thin slurry may be used, depending on the amount of smoke mixture to be neutralized.

(C) Laundry soap in water is very satisfactory for cleaning tanks, etc. The soapy water, being an alkaline liquid, neutralizes the acids and possesses a cleansing action characteristic of soap.

#### 5. Decontaminating Agents for Vesicants

(A) RH-195 is a light tan or white powder which gradually decomposes, giving off a chlorine-like odor. This agent must be dissolved in a solvent such as acetylene tetrachloride just prior to use, since slow deterioration takes place after mixing.

(1) RH-195, also called noncorrosive decontaminating agent, is relatively harmless, but the solvent, acetylene tetrachloride, is toxic in both the liquid and vapor state, so care should be exercised in handling it. Continued absorption of the liquid through the skin is harmful, and the same is true of the continued breathing of its vapors. If the liquid is splashed on the body, it should be washed off with soap and water as soon as possible. When working with it there should always be plenty of ventilation, and personnel always kept to up-wind of the source of the vapor. If a high concentration of the vapor is formed, personnel working with the material must wear gas masks.

(2) A solution is made by dissolving 1 part of the agent in 15 parts of acetylene tetrachloride, all parts by weight. Any large can, drum, or wooden tub may be used for the preparation of the solution. The same strength solution is obtained by using 1 part agent and 6-1/4 parts acetylene tetrachloride, all parts by volume. The liquid should be stirred with a wooden paddle until all of the agent has been dissolved, then it is ready for use. About 1-1/2 gallons of this solution should be adequate to decontaminate a spray tank or 15 square yards of contaminated area.

(3) RH-195 solution is one of the most effective decontaminating preparations known, but unfortunately it is expensive, so its use should be limited to contaminated equipment. The solvent, acetylene, tetrachloride, should never be mixed with diluted alkalies, such as washing soda or lye solutions, etc. due to the fact that the mixture may produce explosive compounds. Some of its other disadvantages are its toxicity, obnoxious odor, tendency to soften rubber and remove paint,

and the formation of hydrochloric acid through the acetylene tetrachloride when in contact with moisture. The powder is stable in storage, but the solution loses its effectiveness after about three months. RH-195 is the standard shipboard decontaminating agent.

(B) Bleaching powder, also known as calcium bleach, chlorinated lime, and chloride of lime, is a white substance containing about 35 percent available chlorine. It gradually decomposes in storage and is easily recognized by its chlorine-like odor. Containers should not be so thoroughly sealed that high internal pressures created by the decomposition of the bleach cannot escape. Bleaching powder is very corrosive to most metals (very slight to monel) and fabrics, but nevertheless it is the most commonly used decontaminating chemical ashore.

(1) Bleaching powder will destroy or convert vesicants into less toxic compounds by oxidation and chlorination; however, the oxidation product of lewisite is a solid which is toxic to the touch. Dry bleaching powder reacts violently with liquid H, evolving a great deal of heat which usually ignites the H vapor; therefore, it is normally mixed with water or some absorbent before application to contaminated surfaces. Care should be taken not to breathe excessively of its dust, as it has a very irritating effect upon the lungs and throat. If spilled upon the skin it should be washed off with water. It is not dangerous, but irritating.

(2) Bleaching powder is most commonly mixed with water in equal proportions by weight, or about three shovelfuls of bleach to two gallons of water, making a slurry. About 1-1/2 gallons should be sufficient to decontaminate a spray tank or 15 square yards of contaminated area.

(3) Because of its relative cheapness, availability, and effectiveness, bleaching powder is the standard decontaminating agent ashore. However, suspensions of it are difficult to maintain, it deteriorates rather rapidly (average chlorine loss is one percent per month), corrodes most metals, cakes in storage, and becomes difficult to remove from its container. Persons handling any considerable quantity of it are forced to wear masks and must expect their clothing to be damaged.

(C) Caustic soda, chemically sodium hydroxide, is commonly called lye; it is a white solid easily dissolved in water. It destroys most non-metallic substances upon contact when in the presence of moisture, but only long periods of exposure produce any appreciable corrosion to monel or steel. It hastens hydrolysis of vesicants by neutralizing free hydrochloric acid. Solid caustic soda is stored in iron drums which have been sealed so as to prevent the absorption

of carbon dioxide and water from the air. Solutions of caustic soda must be kept in glass containers equipped with rubber stoppers. Caustic soda is dangerous to handle since it attacks the skin, eyes, and clothing. It does not give off a poisonous vapor but is very poisonous if swallowed. Workmen should wear goggles and respirators or caustic-proof hoods, rubber gloves, rubber aprons, wooden or rubber shoes, and rubber puttees (leggings), or boots. If any particles touch the skin, they should be washed off with copious amounts of water, followed by a wash with a two percent solution of acetic acid, if available.

(1) Aqueous (water) solutions are effective in most proportions, but the more concentrated solutions provide speedier decontamination. Surfaces which would be corroded by a strong aqueous solution should be treated with an alcoholic solution containing five percent caustic soda. This is prepared by adding five parts of caustic soda to 95 parts ethyl alcohol, all parts by weight.

(2) Solutions of caustic soda are very effective for decontamination of most vesicants, particularly lewisite. Being a true solution, it has greater penetrating power than slurry. Solutions of it can be diluted sufficiently to make a relatively inexpensive decontaminating agent. The injury to the skin of personnel and the corrosive effect on treated surfaces are greater than that of bleach.

(D) Soap has a strong absorptive power towards most substances, including vesicants, and carries them away. The great lowering of the surface tension of water and the increase in its wetting power by soap permits the soapy water to slip in between particles and loosen dirt. Mustard gas is emulsified and carried off as minute droplets by soapy water. Strong soap (like laundry soap) contains some sodium hydroxide which hastens hydrolysis of vesicants by neutralizing the free hydrochloric acid usually formed, making soapy water very effective against lewisite since L oxide, the toxic solid, must be washed away in any event.

(E) The most common solvents used in decontamination are gasoline, kerosene, motor oil, carbon tetrachloride, alcohol, and acetylene tetrachloride. However, most hydrocarbons and oils will dissolve vesicants.

(1) Solvents must be used carefully so as not to spread contamination to clean surfaces. They are best applied to swabs, which are then used to clean small areas and discarded. It should be borne in mind at all times that solvents do not destroy chemical agents, but simply dilute

them. If an area is repeatedly scrubbed it will be freed of most contamination if the swabs are changed frequently.

(F) Steam may be classified as both a hydrolyzing and incinerating material, since the heat proves very effective in driving off or breaking up any injurious chemical agents. Steaming of spray tanks is the standard decontamination method ashore. Spray tanks used with H or mixtures containing H should be steamed at least 3 or 4 hours (H hydrolyzes slowly), while those used with L or the nitrogen mustards should be steamed at least 1/2 hour (L and the nitrogen mustards hydrolyze readily).

Chapter 9

*1 July 1943*

Storage and Inspection of Filled Tanks

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1. General - Liquid chemical agents should be stored in a cool, dry, fireproof storage place which has sufficient ventilation to vent any vapors, which might collect due to a leaking container, to the open atmosphere. The floor of the storage place should be made of steel or a specially treated, non-absorbent concrete (sodium silicate is a suitable treating agent); wood or any rubberized materials should never be used for flooring. The floor should also be provided with a drainage system which will permit the storage place to be readily drained should it become necessary to wash the storage place with an abundance of water and/or decontaminating agent. Smoke screen tanks or other containers filled with a liquid chemical agent should be placed on racks or stands; these racks or stands should be so constructed that each container (or metal or wooden stand and container) is readily removeable in case of leakage, fire, or other emergencies.

(A) Each storage place or magazine should have a set of first aid and decontaminating instructions and gas warning signs posted in a conspicuous place.

(B) Decontaminating and first aid materials should be kept on hand whenever handling chemical agents. If practical, first aid and decontaminating agents also should be stored in and near the chemical warfare magazine or storage places.

(C) On board ship, selection of storage space for filled spray tanks should be such that any leakage would not allow vapors to spread through the interior portions of the vessel. To this end, the mechanical ventilation of the space involved should be so operated as to exhaust possible fumes from the storage compartment direct to the weather, or if the space involved is topside (astern), a rapid and safe means of jettisoning the tanks in an emergency should be provided.

(D) The temperature of the storage place should be kept below 110°F. since the stability of the chemical agents is appreciably decreased at higher temperatures.



(E) The loaded tanks should never be stored in the direct rays of the sun or near artificial heat except, of course, during extremely cold weather when the object is to keep the chemical agent from freezing before contemplated use.

(F) Liquid chemical agents should not be stored with any type of ammunition.

(1) Vesicants are not inflammable and are only slightly corrosive (excluding mixtures) to metals; their chief danger is to personnel because of their exceedingly toxic nature.

(2) Smoke mixtures (like acids) are extremely corrosive to most metals and attack most all materials, but are not inflammable themselves (see paragraph 2 below). Containers filled with smoke mixtures should not be stored with nitrates, metallic powders, carbides, picrates, fulminates, or combustible materials.

(3) If storing different chemical agents in the same storage place or magazine, the odor resulting from leaks or loosely sealed containers of decontaminating agents, etc., may complicate the detection by odor of any particular vapors; hence, it may be desirable to store different agents separately or to remove temporarily certain chemical agents in order to identify an agent by a process of elimination.

(G) Aboard ship, containers of chemical agents which are stored topside or below in magazines should be inspected daily; on shore, weekly inspections of containers should suffice.

(H) Monel containers filled with vesicants or smoke mixtures should not be vented if filled to only 90% capacity. Periodic venting may temporarily reduce the danger of the chemical agent's spurting out should a valve be accidentally opened when liquid is in contact with the valve, but due to the inherent dangers in venting tanks and the fact that tanks vented on cold days may actually have a negative pressure, the practice of venting tanks in an effort to make them safer may actually do more harm than good. Steel containers (filled to 90% capacity) need venting only when filled with the impure plant H which contains substances that react with iron and cause pressure.

2. Fire - If a fire involves or threatens spaces where chemical agents are stored, all personnel within the danger zone should be notified to vacate this area (move to windward side) until the danger is past. Since such a fire is extremely dangerous, special precautions should be taken to prevent fires in areas where chemical munitions are stored.

(A) H and L are not inflammable and are, therefore, not a fire hazard themselves. However, the vapors of these vesicants are extremely dangerous and all fire fighters who may be exposed to vesicant vapors should be completely protected by wearing protective clothing and gas masks.

(B) FS and FM are not combustible themselves, but they may cause fires by coming in contact with water or grease, or by the heat generated when smoke mixtures come in contact with combustible materials. Should containers of FS or FM burst in a burning magazine or building, a large volume of smoke will be generated, creating the additional hazard that men attempting to fight the fire may become lost. Personnel, therefore, should not be permitted to enter a burning magazine or building unless equipped with life lines.

3. Preparing a Tank for Storage - Immediately after a smoke screen tank has been filled with a chemical agent, the tail cone assembly or the blank flanges (Mark 5 type smoke screen tank), or the filling plugs (Mark 7 type smoke screen tank), should be installed on the tank (see Chapter 7 on Filling). All exterior surfaces of the tank which may have become contaminated during filling should then be thoroughly decontaminated. The tanks should then be checked for leakage. Any tank which is leaking should have its contents transferred to another tank or back to a shipping drum. A leaky discharge valve on the Mark 5 type smoke tank may sometimes be corrected by standing the tank with the valve end up and opening and closing the discharge valve several times permitting the valve to close quickly each time. Tanks which are not leaking and which do not have any chemical agent on their external surfaces may be placed on racks or stands in the storage place. Each tank should be accessible for inspection, and provision should be made so that if a tank develops a leak, it may be easily removed.

(A) The Mark 7 type smoke screen tank is not recommended for storage longer than several days (see Chapter 6, paragraph 5).

(B) It is recommended that the tail cone assembly, rather than blank flanges, be installed on the Mark 5 Mods 2 and 3 tanks which are filled with a vesicant to be carried aboard ship. This procedure will eliminate the potentially dangerous operation of later removing the blank flanges and installing the tail cone.

(C) If HL, a mixture of H and L, should be used, the mixture can be expected to be a very corrosive (negligible to monel) and to develop sludge and pressure within any tank. While H, L, and a mixture of H and monochlorobenzene (as well as other stabilizing diluents) may be stored for long periods (at least 6 months) at normal temperatures without losing their vesicant properties, HL should not be stored for periods longer than two weeks at any temperature since the vesicant properties decrease considerably after about a month.

(D) The tags on loaded tanks should be checked to see that they are legible and contain the pertinent details such as the name of the chemical agent(s), date, temperature, place of filling, the weight of the contents, and maximum storage period before inspection for decomposition, sludge, etc. (inspection to be made at filling depots).

(E) The loaded Mark 5 type tank should be stored in a vertical position with the tail cone up, in order to keep the corrosive agents away from the valves and in order to deposit possible sludge away from the inlet and exhaust openings.

(F) The loaded Mark 7 type tank may be stored in any position that will not allow the air scoop and discharge tube to become bent or otherwise damaged.

4. Detection and Disposition of Leaking Tanks - The sense of smell ordinarily should not be relied upon too heavily to detect mustard, lewisite, or other vesicants since light concentrations are sometimes practically odorless and are difficult or impossible to detect in this manner. Also the sense of smell alone is sometimes unreliable because of "fatigue" of this sense, and in the case of smokers, because of a decided insensitivity. Since the danger of a long exposure to light concentrations can be as great a casualty menace as is a short exposure to high concentrations, the earliest detection of vesicant vapors and maintenance of proper ventilation is of the utmost importance. Therefore, frequent inspections of the magazines for the detection of possible leaking containers is essential.

(A) Listed below are eight basic principles for identification of chemical agents by odor:

- (1) Do not inhale deeply; sniff.
- (2) Sniff only once. Repeated sniffing dulls sense of smell.
- (3) First sniff, then think. The memory of odors can be trained by practice.
- (4) Every perception of odor must be named. Learn odors by the memory of the thing sniffed rather than by name of something else.
- (5) After each test, breathe out strongly through the nose several times. Do not sniff a new sample until the old perception of odor has vanished.
- (6) Do not smoke while sniffing. Smoking dulls the sense of smell.
- (7) Do not forget that sometimes a heavy concentration of an agent may be odorless.
- (8) Select for gasentry a man with a trained sense of smell.

(B) The M-9 Chemical Agent Detector Kit, recently standardized by CWS, will detect and identify dangerous vapor concentrations of at least 11 chemical warfare agents, including those containing arsenic. Four other items of chemical warfare equipment for vesicant gas detection are still useful and were standardized years ago by the Chemical Warfare Service; these are the M4 H Vapor Detector Kit, the M5 Liquid Vesicant Detector Paint, the M6 Liquid Vesicant Detector Paper, and the M-7 Vesicant Detector Crayon. It should be kept in mind that fumes from strong acids (smoke mixtures) may interfere with some of the detector tests or give reactions similar to that produced by vesicants. The above items or similar equipment, obtainable through the Bureau of Ships, provide means for detection of vesicants, both in the liquid and vapor form. The presence of H vapor may be detected by the use of the highly sensitive M4 H Vapor Detector Kit, and the particular leaks (liquid form of principle chemical agents) may be discovered by use of the M7 Vesicant Detector Crayon. The M5 Liquid Vesicant Detector Paint, and the M6 Liquid Vesicant Detector Paper also may be used to detect surfaces contaminated by a liquid vesicant. All vesicant detector kits include instructions for their use.

(1) As already pointed out, H vapor (even in odorless concentrations) can be detected by using the M4 H Vapor Detector Kit which is sensitive to very low concentrations. After vapors are discovered, the particular leaking container(s) can best be determined with the M7 Vesicant Detector Crayon by sprinkling the joints, threads, tank surfaces, etc. with shavings of powder made from this crayon. The bright pink powder or scrappings will turn blue if it comes in contact with a liquid vesicant or a high concentration of H vapor.

(2) If the vesicant detector crayon is not available, a slurry of bleach (chloride of lime and water) may be used to distinguish drops of water from vesicant, but only if the tank is outside and downwind from personnel and equipment. It will cause considerable heat and possibly smoke to be produced at leaking points on containers. If there is enough liquid vesicant present, the materials are apt to burst into flame on contact, and this would cause vesicant to spread rapidly into the air; therefore, a gas mask and protective clothing should be worn by each person detecting leaks and decontaminating tanks in this manner.

(C) When a leaking container is discovered, the officer in charge of the chemical warfare materials (or in his absence, another responsible officer) should be notified so that he may take personal charge of the disposal of the leaker. If leakage of any vesicant loaded tanks cannot safely be corrected, such tanks should be cast overboard into deep water and preferably at least a mile away from shore. When practicable, defective smoke tanks (leakage stopped but still under suspicion) should be turned in to the nearest filling depot. Leaking points of a tank should be immediately put at the highest level to prevent escape of the liquid chemical agent.

(D) Leaking containers that are filled with a smoke mixture may usually be detected by the presence of a small amount of smoke or fog coming from the leaking container. If the leak cannot be stopped, the leaking tank should be removed and its contents transferred to a tight container. Aboard ship, if this is not practicable under the circumstances, the contents of the leaking container should be emptied into the sea or the loaded container cast overboard to prevent smoking. Since the vapors from smoke mixtures are not toxic, gas masks are worn for comfort only, but personnel handling smoke mixtures should protect themselves with acid proof clothing or aprons and neoprene gloves.

5. Surveillance - No surveillance tests of the chemical agents stowed in containers aboard ship is necessary other than detection of leaks, etc. Smoke screen tanks filled with FS, FM, H or L will keep at least 6 months in monel tanks with the special gaskets (reference Ordalt No. 1499); however, if leaks develop, the loaded tanks should be disposed of in accordance with paragraphs 4 (b) and 4 (c) above. Smoke tanks loaded with HL should be turned into a filling depot after being stored for approximately (2) weeks, and after about one month's storage the vesicant value should be considered too low for chemical warfare use, even under ideal storage conditions. This fact makes it desirable to store H and L separately mixing them just before contemplated use. H and L are mixed usually to lower the freezing point of H for use in cold weather, and it will be noted that this is the only case wherein filling operations aboard ship may be desirable, and that under ideal cold weather conditions (very low volatility). Other methods of preventing H from freezing may be used aboard ship (see Chapter 2, paragraph 5 and Chapter 3, paragraph 7).

*1 July 1943*

Protection, Precautions, and First Aid for Chemical Agents

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1. Protection Required Against Vesicants - It is necessary for all personnel engaged in handling vesicants to protect themselves from both contact with the liquid and exposure to the vapors. Complete protection requires that the entire body be protected as the liquid vesicant readily penetrates ordinary clothing, or shoes, and even rubber at a lesser rate. The same is true with vesicant vapors, it permeates the clothing and attacks the skin, especially those areas that perspire more freely.

(A) Complete protection requires that a gas mask be worn to protect the eyes, respiratory tract, and face; the rest of the body then must be protected by specially impregnated clothing. The use of such impregnated clothing should always be augmented by a hot bath using a strong soap as soon as the clothing has been removed.

(B) A suitable outfit for personnel who are handling vesicant containers or munitions, or engaged in decontamination work consists of a gas mask, impregnated suit of blue denim or white drill (Arnzen) cloth, woolen gloves, socks, and shoes, all impregnated.

(C) Protective ointment M-4 is issued for application to insufficiently protected areas such as wrists, hands, and neck, and for prophylaxis. When rubbed on the skin, this ointment will protect against high vapor concentrations and will also furnish considerable protection against liquid drops of a vesicant.

2. Safety Precautions - Vesicants

(A) First aid and decontaminating materials should be on hand whenever working with vesicants. A person working with toxic gas or other dangerous material should have an assistant with him at all times.

To be effective, first aid treatment must be given immediately. If liquid H is removed from the skin within three minutes after contact is made, it is probable that no severe burn will result. H should be removed within one minute to prevent serious injury. Any person exposed to a vesicant without sufficient protection should be given medical treatment without delay.

(C) Clothing which has become contaminated with a liquid vesicant should be removed and decontaminated as soon as possible after leaving the contaminated area. If the contamination is great, the clothing should be disposed of by burning or burying. If burned, an isolated location should be chosen in order that toxic fumes which are driven off by the heat will not be blown toward personnel or animals. In any event, the contaminated clothing must be removed from the vicinity since the vesicant on the clothing is a source of further contamination from its vapors or by direct contact.

(D) Great care must be taken to prevent spilling even the smallest quantity of the liquid. Should any spillage occur, the area contaminated must be immediately decontaminated.

(E) Liquid vesicants are readily absorbed by porous materials such as wood, concrete, paint and complete decontamination becomes exceedingly difficult. Immediate action facilitates decontamination.

(F) Great care must be taken in opening containers of vesicant, especially those containers having a mixture of one or more vesicant, because of the pressure which may have developed due to the formation of gases. Vapor fumes and even liquid may be ejected through the opening by the internal pressure thus built up; therefore always stand on the windward side of the container.

3. Identification of Vesicant Agents - The ability of the individual to recognize chemical agents by their odor is of extreme importance. Personnel of combat crews who will perform chemical missions and all other personnel employed in the handling of chemical agents should be proficient in identifying the various agents which may be used (see Chapter 9 , paragraph 4).

(A) Even in harmless concentrations, the presence of mustard and lewisite (not purified) is exposed by their characteristic odors, garlic (H) and geranium (L). This early warning must not be ignored, for though the concentration may be too low to be in itself harmful, it is likely to be sufficient to deaden the sense of smell so that personnel might be unaware of a dangerous increase in concentration.

(B) Because of the faint odor associated with nitrogen mustards and purified vesicants, it is essential that some chemical method of detection be employed. There are three standard methods now available.

(1) Detector paint or paper will change to bright red color in contact with liquid H, L, ED, or nitrogen mustards, but is not affected by the vapors of these agents. By exposing it widely, sprayed vesicants are readily detected providing frequent inspection is made.

(2) Kit, Vapor Detector M-9 will detect the presence of vapors of the various gases, including those containing arsenic. It will be of special value in cases of odorless or non-irritating toxic gases in the presence of other odors and in establishing the absence of any poison gas.

(3) Crayon vesicant detectors are useful in detecting definite spots of vesicants on material, etc. A special crayon for nitrogen mustards is being developed although it is not yet standardized.

4. Symptoms of Vesicant Poisoning - The symptoms of vesicant poisoning are delayed and usually do not appear until 15 minutes after contact with the liquid (L causes immediate pain); if exposed to vapors the symptoms usually do not appear until 2-4 hours after exposure and may be delayed as long as 48 hours. The symptoms are as follows:

(1) A sensation of grit in the eyes, followed quickly by reddening of the eyes and eyelids and tear flow.

(2) Reddening of skin surface followed by swelling, especially of moist areas, and later development of blisters.

(3) Hoarse cough, expectoration, and severe pain in the chest.

(4) Nausea and vomiting, if any of the gas has been swallowed.

#### 5. First Aid - Vesicants

(A) The application of immediate first aid measures is of the greatest importance to individuals who have been subjected to vesicant agents. If the liquid vesicant is completely removed from the skin within three minutes (H) or one minute (L) after contact, it is probable that no severe burn will result and further medical treatment is usually not required. It is essential that all personnel be trained in the immediate action to be taken in case they become contaminated. After about ten minutes for persons exposed to L and thirty minutes for persons exposed to H, prophylaxis is practically ineffective; in fact, protective ointment or



chlorinating agents should not be used after inflammation appears as they will increase the irritation. The symptomatic treatment applied after injury has been produced is usually quite different from the specific preventative treatment, and usually does little to prevent further damage. In general, the specific treatment of injuries caused by chemical agents does not differ from that of similar conditions occurring from other causes; for example, the after treatment of a skin lesion caused by mustard is the same as that for any ulcerative lesion of the skin of like degree.

(B) Prophylaxis for Mustard (Skin) - To be effective, prophylactic measures must be instituted within a few minutes. Immediate prophylaxis is effective following liquid contamination, but of little use after exposure to vapor since in this case practically all of the agent has already penetrated the skin. After getting out of the gassed area contaminated clothes must be quickly removed, using the proper precautions not to spread the contamination. The continued wearing of clothing contaminated with mustard, liquid or vapor, will cause severe burning of the skin. The clothes removed should be segregated until decontaminated, burned, or buried. A careful technique must be followed for the removal of liquid mustard from the skin, otherwise such attempts merely serve to spread the agent. Three steps are necessary.

(1) First. Dry pads are gently applied to absorb any mustard remaining on the skin. This action is one of dabbing, not rubbing. Fresh pads should be used for each dabbing so as not to spread the agent to uncontaminated areas.

(2) Second. The treatment agent is applied. The following four methods of prophylaxis are recommended:

(a) Protective ointment - Protective ointment M-4 gives excellent prophylaxis if used properly and immediately. It is to be used by the individual on himself as soon after contamination as possible. A small amount of ointment is squeezed onto a piece of gauze, cotton waste, handkerchief, piece of shirt, or similar material and rubbed vigorously on and around the affected area for 10 to 20 seconds. The ointment is then wiped off. This procedure of applying, rubbing, and removing the ointment is repeated three or four times. Protective ointment should not be used if inflammation has appeared.

(b) Dichloramine - T in triacetin - Gently and repeatedly dab the affected areas with gauze (or other similar material) moistened with a 20 percent solution of dichloramine -T in triacetin. This method should not be used if inflammation has appeared.

(c) Solvents - Solvents such as gasoline (unleaded), kerosene, carbon tetrachloride, alcohol, etc. may be used. A very careful technique must be followed. The solvent must not be allowed to run from the contaminated to the unaffected skin as it will carry the vesicant and extend the damage. The sponging material should be dampened but not saturated with the solvent. The cleaning action should be that of dabbing, not rubbing. Only this method should be used if inflammation appears before first aid has been instituted. Vapor burns should not be treated with solvents.

(d) Hypochlorites - Products containing active chlorine, such as bleach (grade A calcium hypochlorite), or sodium hypochlorite (Dakin's solution) may be used. Bleach may be used as a paste, 1 part to 1 or 2 parts of water. Because of the irritant properties of bleach paste, it must be washed off with water in 3 minutes. This method is recommended for decontaminating the hair. Do not use this method if inflammation has appeared.

(3) Third. Following methods in (b), (c), and (d) above, the skin area is washed with soap and water and patted dry. Following method in (a) above, the ointment is washed off with soap and water when the tactical situation permits. The sponging materials contaminated in the process should be burned or buried.

(C) Prophylaxis for Mustard (Eye). Liquid mustard in the eye demands immediate irrigation with 2 percent sodium bicarbonate solution, saline, or plain water, continued for 10 minutes. If irrigation cannot be instituted within 5 minutes, it should not be done at all. Washing the eye with water, when sodium bicarbonate solution is not available, may be done, unless in the immediate vicinity of medical aid, since time is the controlling factor. not Rubbing the eye must be avoided. Vapor burns of the eye should be irrigated. Sodium bicarbonate solution should also be used for a throat gargle and mouth wash.

(D) Prophylaxis for Lewisite (Skin). In general, lewisite acts more quickly and more painfully than mustard. Prophylaxis against skin contamination with liquid or vapor lewisite should be instituted within 1 minute after exposure since skin penetration is rapid. After getting out of the gassed area contaminated clothing must be quickly removed with usual precautions and treatment, if possible, started at the same time. The same three steps as for prophylactic treatment of mustard are used, though the specific remedies differ.

(1) First. Liquid drops are removed by quickly blotting with dry absorbent material (see paragraph 6(B)(1) for technique).

This step is omitted for vapor burns, but the remainder is the same as for liquid contamination.

(2) Second. Neutralization and removal by one of the following methods:

(a) Protective ointment. Protective ointment M-4 gives effective prophylaxis if used properly and immediately. It is to be used by the individual on himself as soon as possible after contamination. The method is identical with its use for mustard (see paragraph 6(B)(2) above). It should not be used after inflammation has developed.

(b) Hydrogen peroxide. Eight percent hydrogen peroxide is the best available prophylactic for lewisite skin contaminations; if not available, use U.S.P. 3 percent hydrogen peroxide. Fresh swabs should be used for each application and a careful technique used to prevent increase of the injured area due to careless swabbing.

(c) Sodium hydroxide. A 10 percent solution of sodium hydroxide in 30 percent (70% distilled water) glycerin may be used if hydrogen peroxide is not available. The skin should be swabbed alternately with this solution and alcohol. If the glycerin solution is not available, a 5 percent aqueous solution of sodium hydroxide may be used, and water may be used as a less effective substitute for the alcohol (Soapy water, G.I. soap, contains a small amount of sodium hydroxide).

(d) Solvents. If none of the foregoing materials are available, the same solvents and technique described for mustard (paragraph 6(B)(2) above) may be used.

(3) Third. Protective ointment M-4 is removed with soap and water when the tactical situation permits. After swabbing described in (b), (c), and (d) above, the skin should be thoroughly washed with soap and water. Swabs should be burned or buried.

(E) Prophylaxis for Lewisite (Eye). Liquid lewisite causes instantaneous severe pain on contact with the eye and marked spasms of the eyelid. Severe eye lesions are produced by even small drops of liquid lewisite. Although not as severe as the liquid, lewisite vapor also causes marked injury to the eye. Two to four drops of eye solution M-1 should be instilled into a contaminated eye as soon as possible. For maximum effectiveness this solution should be used when and where the injury occurs, by the individual himself, or he

should be treated by the man nearest him. This solution may prevent later damage if used up to 30 minutes after contamination with lewisite liquid. The eye solution M-1 is used once only and is not repeated. In the absence of eye solution M-1 the eye should be promptly washed out with water in the manner described for mustard (see paragraph 6(C) above), whether contaminated by the liquid or the vapor. In the case of spasms of the eyelid, the eye solution may have to be placed in the inner corner of the eye and allowed to spread over the cornea as best it may. The eye solution M-1 is of no value for mustard contaminations but should be used for contaminations by mixtures of lewisite and mustard and for all other arsenical vesicants. Later medical treatment of the eyes may be required.

(F) Prophylaxis for Mixed Vesicants. The use of vesicant agent mixtures may be expected either as premixed agents or as a combination of two agents directed simultaneously on one objective. Such mixtures complicate specific prophylaxis and treatment. Attack first the agent capable of doing the greatest damage, as quickly as possible. It will often be necessary to use more than one medical agent. Lesions produced by a mixture of mustard and lewisite show characteristics of both agents. There are two forms of blistering agents: those which cause only local irritation (like H) and those which cause local irritation plus internal poisoning (like L). These latter compounds usually contain arsenic. The following apply to lewisite and mustard mixtures.

(1) Skin. Protective ointment M-4 should be used by the individual as already directed above. When available, the use of hydrogen peroxide followed by dichloramine-T in triacetin or protective ointment is considered the treatment of choice.

(2) Eyes. If eyes are contaminated, eye solution M-1 should be used immediately, as already directed above, followed as soon as possible by thorough irrigation with a 2 percent sodium bicarbonate solution, normal saline or plain water.

(G) Prophylaxis for Nitrogen Mustards - The gas mask should be put on as soon as the gas is detected, and worn continuously until all danger of exposure has passed. Liquid-splashed clothing should be removed at first opportunity, as for other vesicant agents. The effect on the respiratory tract of humans is not known. However, since the effects in animals are very similar to those produced by mustard vapor, it is believed that the effects in man would be similar. In animals there is marked swelling and irritation of the lining of the nose, throat, and windpipe. The injury is predominately to the upper respiratory tract, but in severe cases the damage extends into the small air sacs of the lungs. The symptoms, in addition to the discomfort in the nose and throat, are hoarseness, cough, and difficulty in breathing.

(1) Eyes. If the liquid agent has entered the eye, it must be washed out by the individual as quickly as possible with water. The eyes are apparently more susceptible to the vapor of the more volatile nitrogen mustards than any other exposed tissue. The less volatile nitrogen mustards are much less effective than equal concentrations of mustard vapor, while the more volatile ones produce damage equal to or greater than that produced by a similar mustard exposure. The liquid forms of the more volatile nitrogen mustards damage the eyes more severely than liquid mustard. An exposure produces in man lacrimation and smarting of the eyes, beginning at once to 18 minutes after exposure. These early symptoms disappear after a few minutes and may be overlooked in ignorance. They reappear at intervals, with increasing frequency and severity, until they finally become persistent about 2 1/2 hours after exposure. Symptoms increase for 8 to 24 hours or longer after exposure. The pupils are contracted. Eye pain on exposure to light is generally present. Long exposures to low concentrations or short exposures to high concentrations of vapor produce severe lesions in the eye. In a more severe exposure the cornea is swollen and cloudy. The conjunctiva is also swollen and bright red. Irritation, lacrimation, and deep eye pain are prominent.

(2) Skin. If the contamination is positively known to be due to nitrogen mustard, soap and water alone are best for decontamination, but it is safer where doubt exists to use first the protective ointment, followed by soap and water, or plain water. If redness has appeared, the use of the ointment should be omitted, and soap and water alone used. Blisters should not be opened until medical treatment is available. The liquids blister the skin more rapidly, but somewhat less severely, than equal amounts of mustard. The redness and blisters resemble those produced by mustard. The blister is translucent, has sloping sides, and is surrounded by a zone of redness.

(3) Vapor contaminations. In vapor contaminations of the skin, eyes, or respiratory tract, the damage has already been done, and it is too late for effective prophylaxis. The vapors are only about one-fifth as damaging to the skin as equal concentrations of mustard vapor. As with mustard vapor contaminations, prophylaxis may do more harm than good; hence, the patient should wait until regular medical treatment is available.

6. General Properties of and First Aid for Smoke Mixtures. Both FM and FS act like heavy acids, especially in the presence of water; however, the concentration of the substances that is encountered in a smoke or fog is very low, and for this reason gives no deleterious effects to either personnel or equipment. In the liquid state these substances must be treated like heavy acids, and all the precautions taken in handling acids should be applied when handling smoke mixtures. Extreme caution is necessary not to spill any of the liquid on personnel or equipment, or to allow foreign substances, especially

greases and water, to come in contact with a liquid smoke mixture as the smoke mixtures react violently with these substances. Personnel engaged in handling smoke mixtures should protect themselves with acid proof clothing or aprons and neoprene gloves. Since the fumes or vapors are not toxic, gas masks need not be worn unless desired; however, personnel should be careful not to inhale the concentrated vapors or unduly expose themselves to light concentrations of vapors for long periods of time.

(A) When water or grease come in contact with an appreciable quantity of a smoke mixture, a large amount of heat is liberated and decomposition of the smoke mixture may take place with explosive violence. This will cause drops of the acid smoke mixture to be scattered around; the area covered and the amount of liquid smoke mixture distributed depends upon the original quantity of the smoke mixture, the quantity of grease and water and the speed of mixing.

(B) When any liquid smoke mixture is spilled, the liquid should be diluted by repeatedly drowning with water and/or neutralized with a sodium bicarbonate solution.

(C) If any liquid smoke mixture gets on the body, it should be immediately wiped off with a piece of dry cloth or waste followed by washing with an abundance of water. A weak solution of sodium bicarbonate and water should then be sponged on the affected area to neutralize the acid smoke mixture. After neutralizing the acid, the skin should then be washed off with water and dried. The affected area should then be treated as for a burn.

(D) In case any of the liquid smoke mixture gets into the eyes, wipe off as much of the liquid as possible and then flush the eye with a one or two percent solution of sodium bicarbonate and water (one or two heaping teaspoonfuls of sodium bicarbonate to a pint of water). Follow this with a few drops of olive oil, castor oil, or medical mineral oil. In case there is no soda solution available, flush the eyes with copious quantities of running water.

(E) If a quantity of liquid smoke mixture (2 or 3 ounces) is spilled on the clothing, remove the garment immediately. Do not put water on the clothing while it is being worn, as the heat of the reaction between the smoke mixture and the water is apt to cause severe burns. The smoke mixture that has soaked through to the skin should then be removed as described above and the clothing thoroughly rinsed with water and put in a saturated solution of sodium bicarbonate.

(F) Personnel who have inhaled excessive quantities of the fumes should be kept quiet and given medical attention at once.